BBC **OBSERVE THE SUN IN DETAIL THIS SUMMER**

#218 JULY 2023

Sky at Night

THE UK'S BEST-SELLING ASTRONOMY MAGAZINE

JWST

A YEAR OF SCIENCE

The telescope's most remarkable discoveries in its first 12 months

CAPTIVATING CRESCENT

Track the changing phase of Venus this month

STARGAZING IN UTAH, THE DARKEST STATE

NEW MISSION TO SOLVE DARK MATTER MYSTERY

VIEW THE DELIGHTS OF THE SUMMER TRIANGLE

NANCY GRACE ROMAN: THE MOTHER OF HUBBLE

LARGE APERTURE IMAGING REFRACTOR ON TEST

Welcome

What a year for the James Webb Space Telescope!

On 11 July 2022, the world got to see the first-ever scientific findings from the James Webb Space Telescope, unveiled by no less a figure than US President Joe Biden, who like the rest of us gazed in awe at its image of galaxy cluster SMACS 0723, the deepest, sharpest infrared photograph of the Universe then seen.

In the 12 months since, there has been no let-up in superlative science finds flowing from Webb – the first analysis of an alien world's atmosphere, new insight into the formation of galaxies in the early Universe, unparalleled detail on the Solar System's gas giants... the list goes on. On **page 28**, Jenny Winder looks at the major discoveries from across each of JWST's four areas of investigation.

The long days of summer are a great time to make scientific enquiries of your own on our nearest star. This is needed more than ever at the moment, as the Sun may have reached maximum activity, its surface often dotted with multiple sunspots. Pete Lawrence is your guide to making safe and accurate observations on **page 34**, with the techniques that will mean your sightings can be added to the scientific record. If you already have a telescope, all you need is a white-light solar filter attached.

You'll also find some lovely night-sky targets in what darkness there is this month, and Stuart Atkinson takes a look at an area rich with them on **page 40** – the Summer Triangle. Easy to find in summer skies, follow his list of 10 of its delights for a quick stargazing fix.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 13 July.

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Sky at Night – lots of ways to enjoy the night sky...

Television
Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 18

Online
Visit our website for competitions, astrophoto galleries, observing guides and more

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CONTENTS

Ⓒ = on the cover

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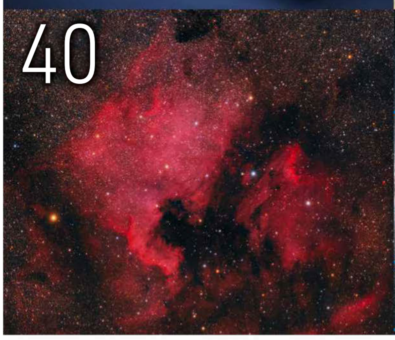
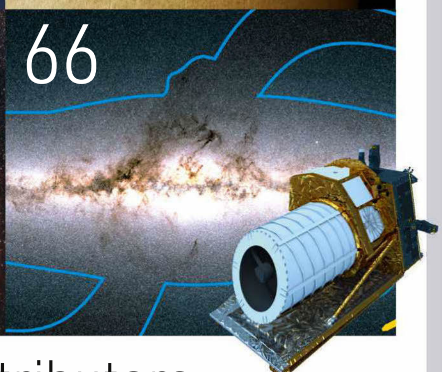
New to astronomy?

To get started, check out our guides and glossary at
www.skyatnightmagazine.com/astronomy-for-beginners





This month's contributors

Jenny Winder

Science writer

"Over its first year of operations JWST has provided us not just with breathtaking images, but with the groundbreaking science that underlines them." **Join Jenny for a deeper look at JWST's discoveries on page 28**

Stuart Atkinson

Seasoned observer

"The Summer Triangle was one of the very first asterisms I learned as a kid. Now I'm grown up, it keeps me company on warm summer nights." **Stuart shows us the top sights in summer's iconic asterism, page 40**

Govert Schilling

Science writer

"We still don't know what 95 per cent of the Universe is made of. I look forward to seeing what Euclid discovers after it launches this summer." **Govert explores the new mission to study the dark Universe, page 66**

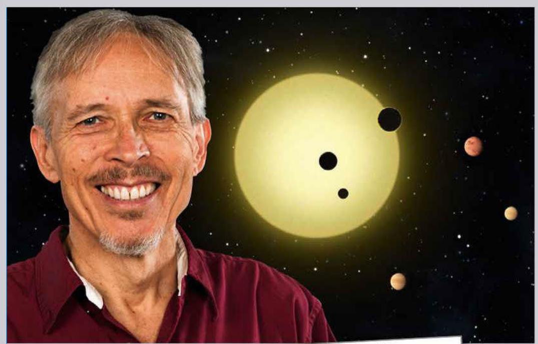
Extra content ONLINE

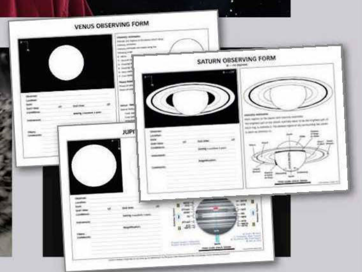
Visit **www.skyatnightmagazine.com/bonus-content/FFHPTFJ** to access this month's selection of exclusive Bonus Content

JULY HIGHLIGHTS

Interview: Searching for Earth 2.0

Astronomer Chris Impey discusses exoplanets and the hunt for habitable worlds beyond our Solar System.





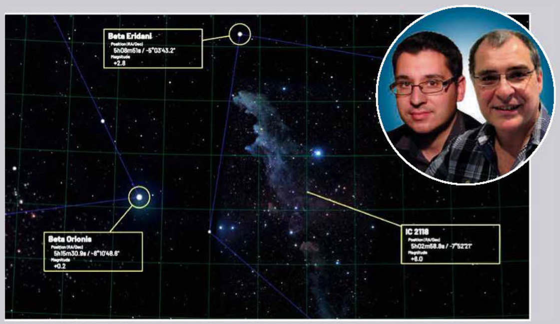
Will an Asteroid Destroy Earth?

In this episode of *The Sky at Night*, Maggie and Chris find out about asteroid detection and planetary defence.

Observing forms and telescope software

Download planetary observing forms and access software to help you with this month's Deep-Sky Tour (page 56).

The Virtual Planetarium



Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

CTIO/NOIRLAB/DOE/NSF/AURA/ T.A. RECTOR (UNIVERSITY OF ALASKA ANCHORAGE/NSF'S NOIRLAB)

SHINING THROUGH THE DARKNESS

A newborn star duo light up their stellar nursery

VICTOR M BLANCO 4-METRE TELESCOPE, 18 MAY 2023

There's a lot to unpack in this stunning image, which was captured recently by the Dark Energy Camera at NOIRLab's Cerro Tololo Inter-American Observatory in Chile, but the stars of the show – literally – are the two bright white dots left of centre.

These are infant stars HR 5999 and HR 6000, formed around a million years ago. Yet to achieve the mass needed for nuclear fusion to start taking place, their heat and light is derived from gravity alone. That's enough, though, for them to light up the gas and dust in their vicinity, thus creating reflection nebula Bernes 149 – the blue haze you see around them. It's also enough for stars and nebula alike to shine out brightly in the middle of the apparently featureless dark nebula Lupus 3. This region, 600 lightyears away in the constellation Scorpius, may look empty, but in reality it's a cloud of dust and gas so dense that it blocks the light from the stars beyond.

△ A supernova on our doorstep

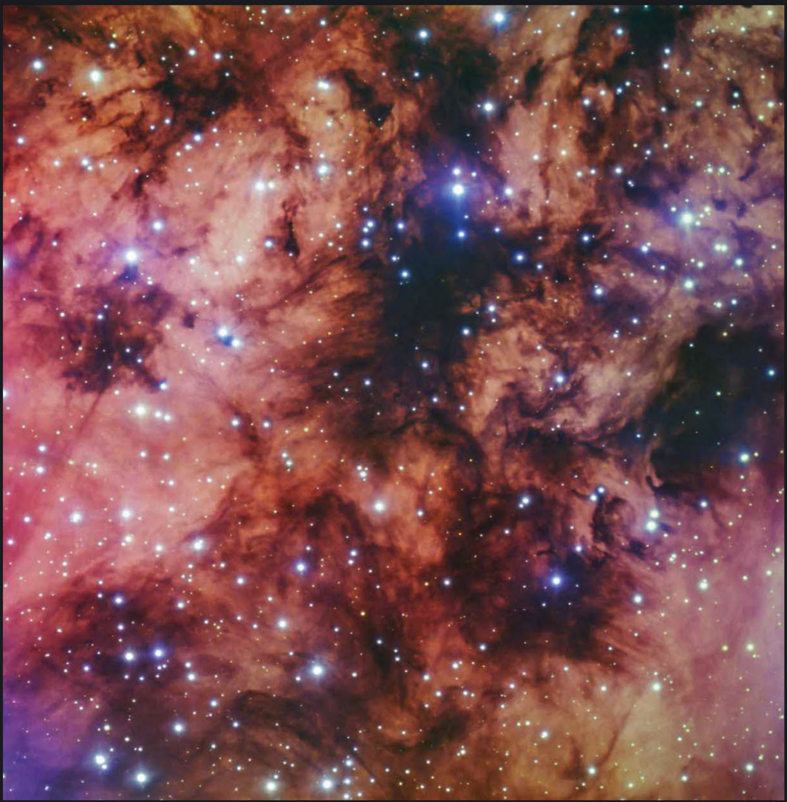
JANE CLARK, 21 MAY 2023

This is Type II supernova SN 2023ixf, spotted in M101, the Pinwheel Galaxy, in May. Remarkably, this shot was captured by amateur astrophotographer Jane Clark using just a ZWO ASI2600MC camera and a Celestron 11-inch telescope. M101 is only 21 million lightyears away, which makes SN 2023ixf the closest supernova seen in the past five years. It's believed a supernova occurs within our own Milky Way every 50–100 years, but as they're mostly within the dust-filled central disc, we can't see them. In fact, only five naked-eye Milky Way supernovae have ever been recorded.

Seeing red ▷

VERY LARGE TELESCOPE, 1 MAY 2023

This picture shows part of Gum 10, one of over 80 diffuse nebulae first observed by Australian astronomer Colin Stanley Gum, who published a catalogue of his discoveries in 1955. The region is densely packed with hot blue stars; it appears reddish due to ultraviolet radiation from those stars ionising the huge clouds of hydrogen that surround them, while the darker areas in the picture are dust clouds.



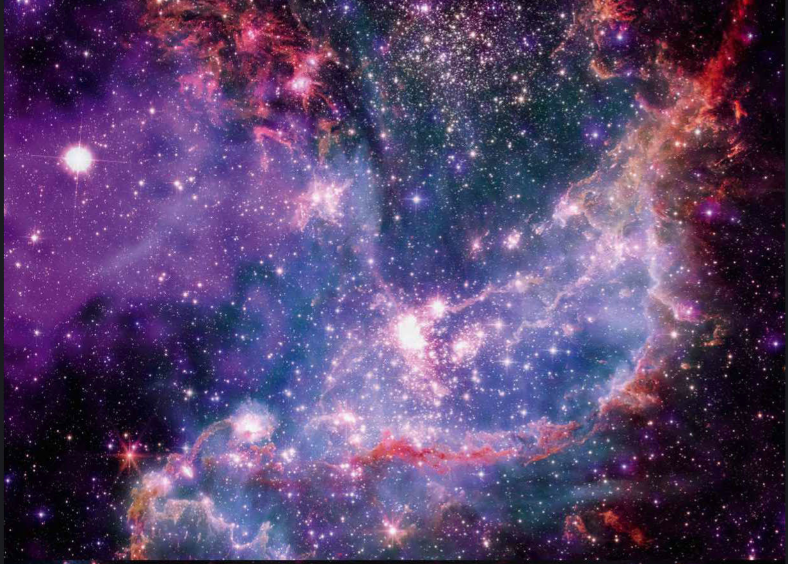
JANE CLARK, ESO, ESO/MEINGAST ET AL, X-RAY: CHANDRA: NASA/CXC/SAO/XMM: ESA/XMM-NEWTON
IR: JWST: NASA/ESA/CSA/STSCI SPITZER: NASA/JPL-CALTECH OPTICAL: HUBBLE: NASA/ESA/STSCI/ESO

Teamwork makes the dream work ▷

VARIOUS TELESCOPES, 23 MAY 2023

These four stunning composite images combine X-ray data from the Chandra X-ray Observatory with infrared images from James Webb Space Telescope, along with further data from the Hubble Space Telescope, ESO's New Technology Telescope, ESA's XMM-Newton satellite and the retired Spitzer Space Telescope.

The result (top to bottom): NGC 346, NGC 1672, M16 and M74 as you've never seen them before. Chandra's X-ray data helps reveal, for instance, the aftermath of a supernova in NGC 346 (the purple cloud on the left of the image) and enables young stars to shine through in the shot of M16, aka the Pillars of Creation, where they appear as pink and purple dots.



△ New visions

VISIBLE AND INFRARED SURVEY TELESCOPE FOR ASTRONOMY, 11 MAY 2023

This infrared image of HH 909 A, a region of dust and gas clouds in the Chamaeleon constellation, was created at ESO's Paranal Observatory in Chile as part of its VISIONS survey, using the VIRCAM instrument attached to the VISTA telescope. It's clearly a case of 'V for victory' here, as the resulting image reveals new regions of intense star formation usually obscured by dust.

MORE ONLINE

Explore a gallery of these and more stunning space images

This was Sylvia's **promise** to you...

A generation ago, a woman named Sylvia made a promise. As a doctor's secretary, she'd watched stroke destroy the lives of so many people. She was determined to make sure we could all live in a world where we're far less likely to lose our lives to stroke.

She kept her promise, and a gift to the Stroke Association was included in her Will. Sylvia's gift helped fund the work that made sure many more of us survive stroke now than did in her lifetime.

Sylvia changed the story for us all. Now it's our turn to change the story for those who'll come after us.

Stroke still shatters lives and tears families apart. And for so many survivors the road to recovery is still long and desperately lonely. If you or someone you love has been affected by stroke – you'll know just what that means.

But it doesn't have to be like this. You can change the story, just like Sylvia did, with a gift in your Will. All it takes is a promise.

You can promise future generations a world where researchers discover new treatments and surgeries and every single stroke survivor has the best care, rehabilitation and support network possible, to help them rebuild their lives.

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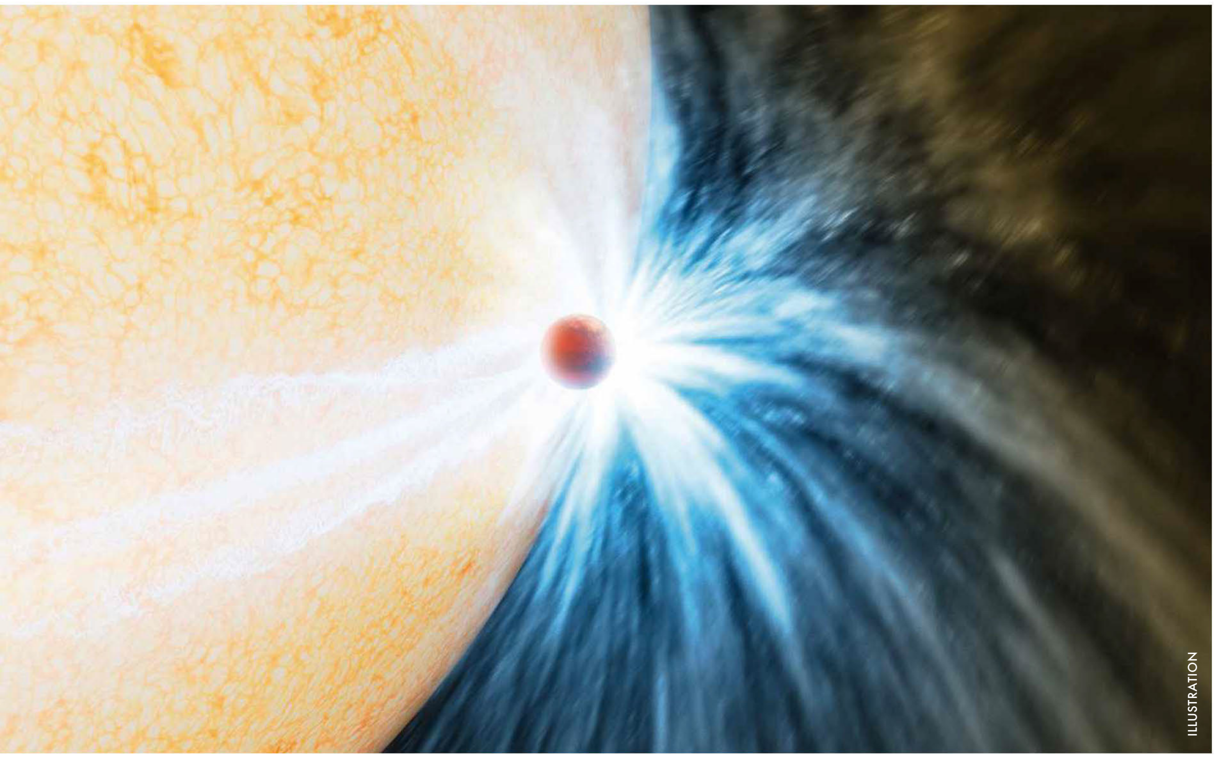
Rebuilding lives after stroke

Stroke Association

The latest astronomy and space news, written by Ezzy Pearson

BULLETIN



▲ **Planetary picnic: ZTF SLRN-2020's brightness but low temperature suggest it ate the Jupiter-sized world**

K. MILLER/R. HURT (CALTECH/IPAC)

Star swallows planet whole

Bloated star gives a dusty belch as it engulfs one of its orbiting planets

A star has been caught in the act of swallowing one of its planets for the first time, giving a preview of our own Solar System's fate.

The star, ZTF SLRN-2020, first attracted attention in May 2020 when the Zwicky Transient Facility in California – which scans the sky nightly – detected it had brightened by over 100 times in just 10 days. Initially, astronomers thought the brightening was caused by two stars merging. However, the star remained bright in the infrared for 100 days after the initial outburst, indicating it was surrounded by a cloud of cold material.

"When a star brightens it usually becomes much hotter," says Kishalay De, who first noticed the star's odd outburst while a PhD student at Caltech and who now works at MIT. "So, low temperatures and brightening stars do not go together."

The energy from the outburst was also 1,000 times less than any previous stellar merger. This ruled out a second star, but instead pointed towards a gas giant planet like Jupiter, which just so happens to be around 1/1000th the mass of the Sun.

The dusty belch from the star was caused by the planet pulling gas from the stellar surface as it spiralled in, ever closer. This gas would have then cooled to form the dust seen in the follow-up observations. A similar fate awaits our own planet, though not for around five billion years. This is when the Sun will begin to run out of fuel and swell to become a red giant, expanding to engulf Mercury, Venus and Earth.

"For decades, we've been able to see the before and after – before, when the planets are still orbiting very close to their star, and after, when a planet has already been engulfed, and the star is giant," says De. "What we were missing was catching the star in the act, where you have a planet undergoing this fate in real time. That's what makes this discovery really exciting."
www.ztf.caltech.edu

Comment
by Chris Lintott

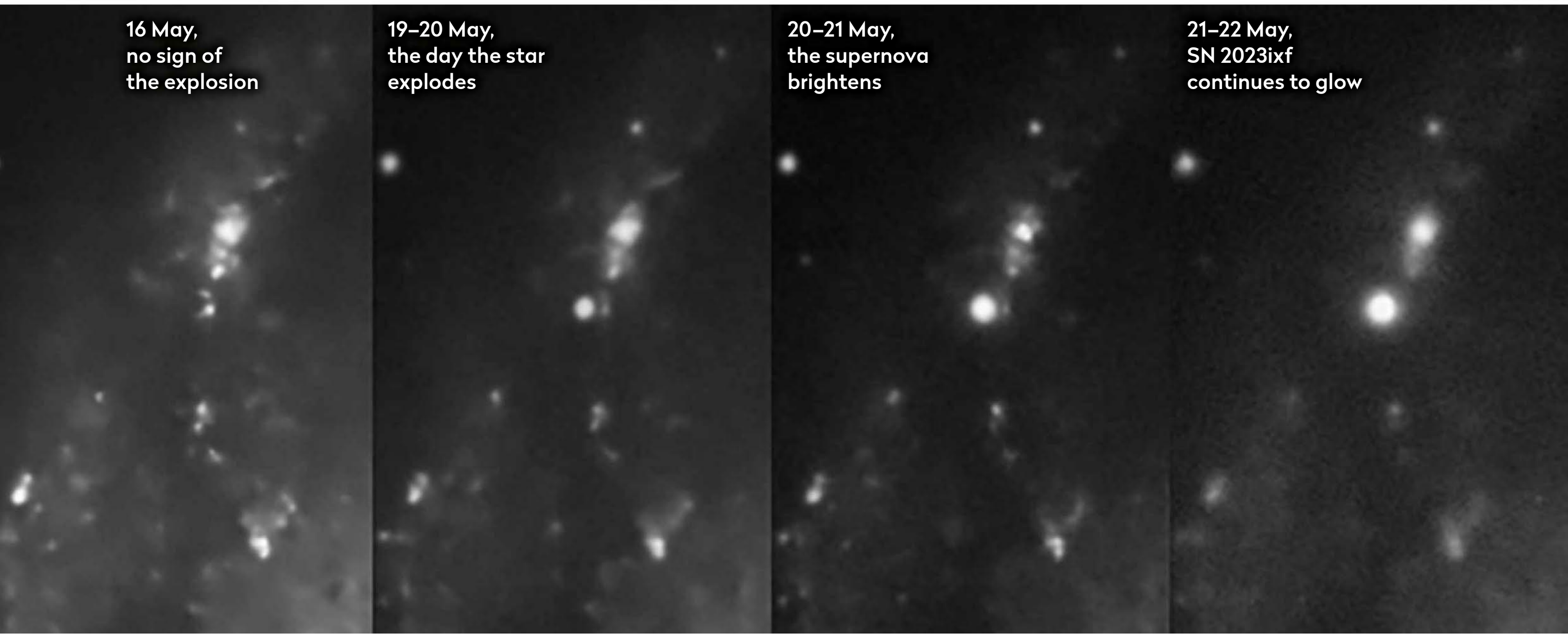
Considering scenarios for what might happen in the dramatic encounters between stars and planets has long been a favourite hobby for an ecletic band of theorists.

One of my favourites is the notion that if a giant planet is engulfed then its moons would be stripped away by tides, ending up as new planets in orbit around the star. Such moons would act as giant comets, producing a debris disc around the star.

Such a series of events has been used to explain the dramatic dimming of Boyajian's star in 2018. It may be that the star ate a planet a century ago, leaving us to observe the effects of its lost moons.

So stars beware: thoughtlessly consuming planets can have consequences.

Chris Lintott co-presents *The Sky at Night*



▲ The Pinwheel Galaxy, M101 is a favourite target of amateur astrophotographers, several of whom found they'd captured the supernova. The above sequence was made by astro imager Martin Bracken from Essex, UK and shows (from left to right) the galaxy before SN 2023ixf's first appearance on 19 May and then through its subsequent changes over the next three days

Supernova found in M101

Explosion is the second star death to be observed in the galaxy in 15 years

The closest supernova to Earth in five years was discovered in the Pinwheel Galaxy, M101, on 19 May by amateur astronomer Koichi Itagaki. The Japanese supernova hunter has more than 100 supernova discoveries to his name. He first noticed this latest event when it was mag. +14.9. It grew to mag. +13.5 just 11 hours later and by 21 May it had reached mag. +11.0, where it seems to have plateaued. Itagaki quickly reported his find, which was then given the designation SN 2023ixf and sent out to the observing community, triggering both professional and amateur astronomers to race to their telescopes.

Located just 21 million lightyears away in the constellation of Ursa Major, the photogenic Pinwheel Galaxy is one of the most imaged deep-sky objects, meaning several astronomers were able to consult their astrophotos from the previous nights to discover they too had captured the brightening star. Fellow amateur astronomer David Kennedy and Bronco Oostermeyer's images of the star taken 33 and 18 hours prior to the 'discovery', respectively, showed that the supernova had gone from a barely visible magnitude +22.0 to magnitude +17.3 in just 15 hours. Meanwhile, Martin Bracken's images from 16 May showed no sign of the stellar explosion at all.

"I was lucky enough to be imaging M101 on the day it was discovered and the subsequent three days," says Bracken, a regular contributor to the Gallery pages of *BBC Sky at Night Magazine*. "The image clearly shows the progression of the supernova over those three days."

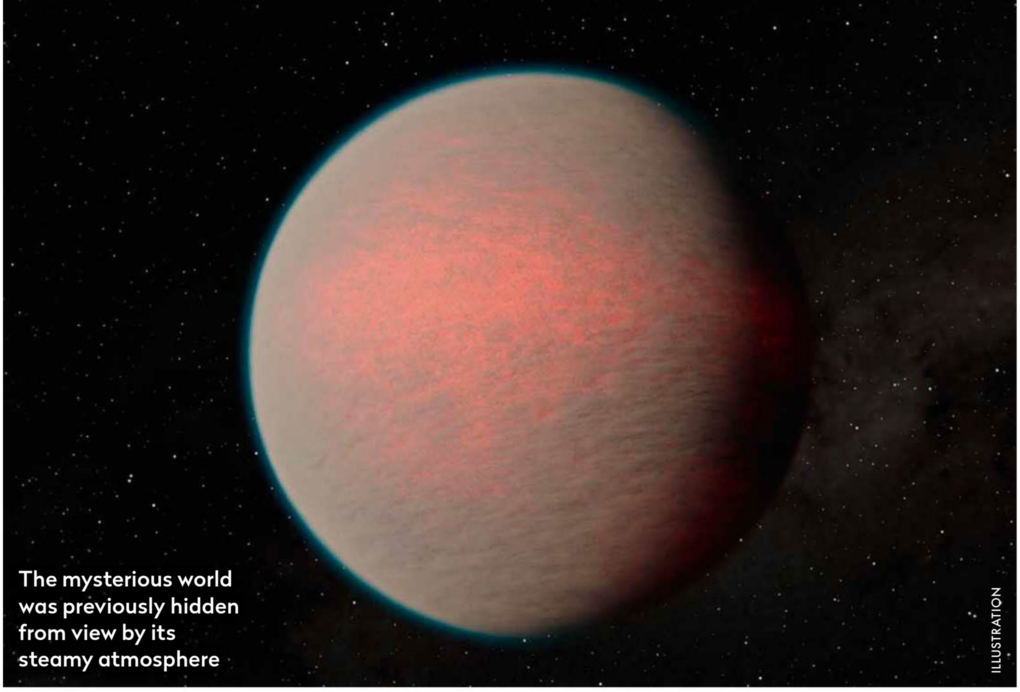
Spectral analysis indicates the explosion was a Type II supernova. These are catastrophic explosions that occur when a massive star with a mass between eight and 40 times that of the Sun no longer has enough fuel to support itself against gravity and collapses to form a neutron star or a black hole. The close proximity of SN 2023ixf gives a unique opportunity to study these stellar explosions. The supernova occured in the southwest region of M101, close to prominent star-forming region NGC 5461. Previous studies of this area found it contained three clusters of young stars, which are common places to find the supergiant stars that eventually go supernova.

A 15-solar-mass red supergiant identified in Spitzer Space Telescope images of M101 taken between 2012 and 2019 could potentially be the origin of the supernova, although this star didn't exhibit the typical fluctuations seen in a pre-explosion star. Further analysis will be required to establish if it is actually connected to the supernova.

If the supernova follows the typical light curve of a Type II supernova then it should remain above magnitude +13.0 for several more months and at a good altitude for UK observing. Most deep-space imaging setups should be capable of recording the supernova, although the light summer nights may make this challenging for some basic systems.

▶ Turn to page 8 to see a full image of the supernova in M101

MARTIN BRAKEN, NASA/JPL-CALTECH/R. HURT (IPAC), NASA/ESA, DOTTEDHIPPO/ISTOCK/GETTY IMAGES



The mysterious world was previously hidden from view by its steamy atmosphere

Mini-Neptune could be surrounded by water

Planet is too hot for life, but gives clues to these common worlds

A distant exoplanet could be surrounded by a steamy atmosphere, according to new measurements by the James Webb Space Telescope. The planet, GJ 1214b, is a mini-Neptune – the most common type of planet in the Galaxy – in a close orbit around a red dwarf star, taking just 1.6 days to orbit. The planet is shrouded in a cloud or haze layer that blocks most observations, but a team led by Eliza Kempton at the University of Maryland compensated for this by watching the planet for a complete orbit.

This revealed that the day side was 279°C, while the night was just 165°C – a disparity that is only possible if the atmosphere contains heavy molecules, such as water.

"We think we detect water vapour, but it's challenging because water vapour absorption overlaps with methane absorption," says Kempton. "We can't say 100% that we detected water vapour and not methane. However, we see this evidence on both hemispheres of the planet, which heightens our confidence that there really is water there." **astro.umd.edu**

Water survives on rare main belt comet

Comet 238P/Read spends its lifetime much closer to the Sun than most comets in the asteroid belt, yet has managed to hold on to its water, according to recent observations by the James Webb Space Telescope.

"In the past, we've seen objects in the main belt with all the characteristics of comets, but only with this precise spectral data from Webb can we say yes, it's definitely water ice that is creating that effect," says Michael Kelley from the University of Maryland, who led the study.

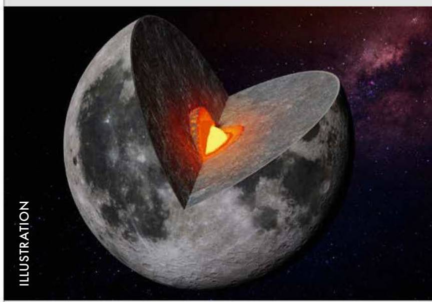
But while 238P/Read's water might have survived the relative warmth of the asteroid belt, the same does not appear to be true for its carbon dioxide. The molecule usually makes up 10 per cent of similar comets, but JWST failed to find any on 238P/Read. This could be because carbon dioxide vapourises more easily than water ice or it could indicate that 238P/Read formed in a warm pocket of the Solar System, free from carbon dioxide. The team hopes to determine which is more likely by observing other main belt comets.

"Do other main belt comets also lack carbon dioxide? Either way it will be exciting to find out," says Heidi Hammel, lead for JWST's guaranteed time observations of Solar System objects. **webbtelescope.org**

Water vapour on a main belt comet is another JWST discovery first

▶ **Turn to page 28 to find out more about JWST's greatest discoveries of the last year**

NEWS IN BRIEF



Lunar core confirmed

Planetary scientists from Université Côte d'Azur have created a profile of the Moon's core using a combination of lunar ranging and orbiter observations. These measurements show the core is 500km across – corroborating previous measurements by NASA – and around the same density as Earth's core.

£50m for UK space R&D

The UK Space Agency has launched a new £50 million fund to grow the British space industry, currently worth £17 billion a year. The Space Clusters and Infrastructure Fund will help improve research and development facilities across the UK, which will be used to build and test new satellites and space hardware.

Plutonium paucity prevents planetary plans

NASA may not have enough plutonium-238 to power a mission to Uranus the agency hoped to begin in 2024. Currently NASA and the Department of Energy is on track to produce 1.5kg a year – sufficient for all spacecraft in production, but delaying the Uranus mission until the 2030s.

NEWS IN BRIEF

Space rock search needs you

Astronomers need your help to search the skies and identify asteroids and comets. Scientists from the Catalina Sky Survey have asked citizen scientists to look through high-resolution images and help uncover the leftovers from the formation of our Solar System. Visit **zooniverse.org** to take part.

Russia commits to ISS

The Russian space agency, Roscosmos, has committed to remaining on the International Space Station until at least 2028. The nation had previously made plans to leave the station next year, but has now announced it will support continued station operations.

Baby galaxies boom in size

Several galaxies identified by JWST as 'too big' for our current understanding of how galaxies grow could be even more anomalous than first thought. A re-evaluation of their mass using a method that better accounts for smaller, fainter stars, found the galaxies could be up to 10 times more massive than initially estimated.

DOTTEDHIPPO/ISTOCK/GETTY IMAGES, JOHN A. PAICE, ESO/M. KORNMESSER

Largest cosmic explosion spotted

Three-year eruption is two trillion times brighter than the Sun

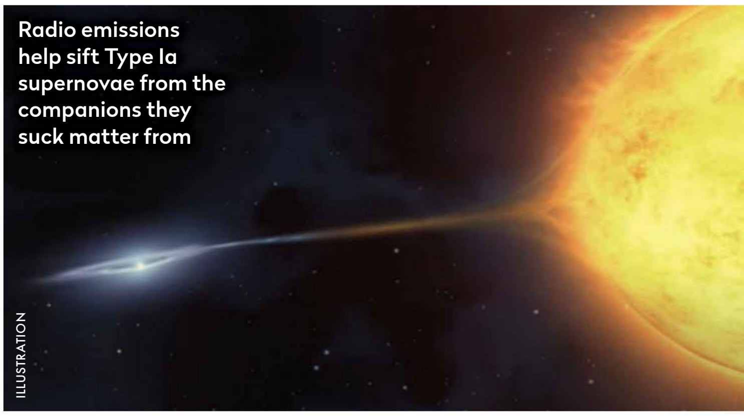
Violent disruption by a supermassive black hole may have triggered the blast

A huge eruption in the distant Universe has now been identified as the brightest cosmic explosion ever witnessed. The event, AT2021lwx, was first discovered in 2020 by the Zwicky Transient Facility, but has continued for the last three years. It is so far away its light has been travelling for eight billion years and is two trillion times brighter than the Sun.

The current leading theory for the cause of the outburst is that a cloud of gas or dust around 1,000 solar masses broke apart as it passed a supermassive black hole. As the fragments were swallowed, it created shockwaves that produced the intense glow.

"With new facilities like the Vera Rubin Observatory coming online in the next few years, we are hoping to discover more events like this," says Philip Wiseman from University of Southampton. "It could be that these events, although extremely rare, are so energetic that they are key parts of how the centres of galaxies change over time." **www.southampton.ac.uk**

UK is first to detect supernova radio emissions



Radio emissions help sift Type Ia supernovae from the companions they suck matter from

Astronomers have successfully detected radio emissions from a Type Ia supernova for the first time after decades of trying, thanks to e-MERLIN, a network of radio dishes across the UK operated from Jodrell Bank.

A Type Ia supernova occurs when a white dwarf star is close enough to a stellar companion that it steals material from it. Eventually the dwarf reaches a critical mass and explodes in a supernova.

Obtaining radio data of these explosions would be extremely useful in understanding the mass and geometry of material around them, but researchers hadn't been able to detect emissions at these wavelengths. That changed when the e-MERLIN team turned their array on SN0220eyj, first discovered on 7 March 2020.

"The exquisite angular resolution of e-MERLIN, combined with its high sensitivity, enabled the radio emission to be pinpointed to the supernova, which is critical for establishing that the multi-wavelength emission was linked and attributed to the same source," says David Williams, e-MERLIN's operations support scientist at the University of Manchester.

Proving radio emissions can be detected from Type Ia supernova demonstrates the value of observing these objects with future generations of radio instruments, such as the Square Kilometre Array. **www.e-merlin.ac.uk**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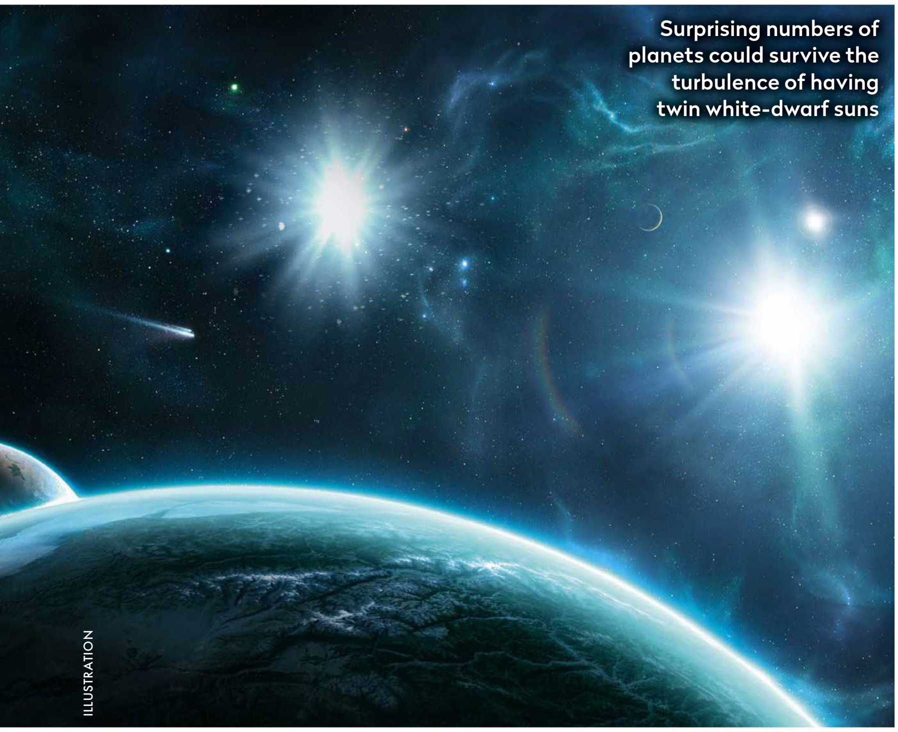
Our experts examine the hottest new research

CUTTING EDGE



Surprising numbers of planets could survive the turbulence of having twin white-dwarf suns

ILLUSTRATION

Building Magrathea

Worlds that orbit two white dwarfs could be relatively common

In Douglas Adams's popular sci-fi series *The Hitchhiker's Guide to the Galaxy*, the wandering characters find their way to a mysterious world named Magrathea that was once at the centre of the custom planet-building industry. In the story, Magrathea is described as an ancient planet orbiting around twin suns in the heart of the Horsehead Nebula. But how common might such planets actually be in our Galaxy?

Gabriele Columba, a PhD student in the department of physics and astronomy at the University of Padua, Italy, and his colleagues have been investigating. The type of planetary system they're interested in is an exoplanet orbiting a binary pair where both partners are white dwarfs – which they dub Magrathea worlds. (Although, here they're considering gas giants rather than the sort of terrestrial planet that features in *Hitchhiker's*.)

A white dwarf is the slowly-cooling remnant left behind after a star has reached the end of its lifetime on the main sequence, puffed up as a red giant and blown away a great deal of its outer gas layers. The process the host stars undergo when they transform from main sequence to enormously inflated red giant, accompanied by a fierce solar wind, is certainly very disruptive for any planet orbiting them. But some ought to be able to survive the ordeal, especially gas giants on wide orbits around the binary pair.

However, while a number of exoplanets have been discovered orbiting binary stars, and there is one confirmed planet orbiting a solitary white dwarf, we haven't yet found a single example of a planet orbiting a binary pair of white dwarfs. Is this because they're rare, or more a consequence of the difficulty in detecting such exoplanets?

Columba and his team ran computer models simulating the life stages of the binary stars, from the main sequence, through red giant to white dwarf, and the effects these transformations have on a single orbiting gas giant. Overall, they simulated over 20,000 different systems, varying the initial masses of the binary stars and orbital distance of the planet. They ran each virtual planetary system until one of several possible outcomes occurred: the binary stars merged together, the planet collided with either star or was gravitationally ejected from the system, or survived for billions of years after both host stars had become white dwarfs – creating a Magrathea world.

"The results show 20–30 per cent of the triplet systems ended up with a surviving planet around a double white dwarf"

Their results show that the formation of Magrathea worlds should actually be pretty common: 20–30 per cent of the triplet systems they simulated ended up with a surviving planet around a double white dwarf, most often on a wide orbit. They also found that of their modelled planetary systems which resulted in the planet on an unstable orbit, the planet was much more likely to become ejected from the system altogether rather than end up crashing into either of the binary stars. And so such evolving binary star systems may represent a major source of free-floating planets in the Galaxy.

This is important work in preparation for the upcoming Laser Interferometer Space Antenna (LISA) mission, which is expected to discover tens of thousands of white dwarf binaries – and hopefully the first example of a 'Magrathea' exoplanet orbiting them.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *Statistics of Magrathea Exoplanets beyond the Main Sequence* by Gabriele Columba et al
Read it online at: arxiv.org/abs/2305.07057

LEV SAVITSKIY/ISTOCK/GETTY IMAGES, DZIKA MROWKA/ISTOCK/GETTY IMAGES

Looking at home from afar

Studying our cosmic neighbourhood from 'outside' is an eye-opener

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

Travel is all very well, but sometimes you can learn more by staying close to home. As astronomers get excited by the views of distant galaxies provided by JWST, it's good to be reminded that we can benefit from paying close attention to our surroundings.

Some of the most exciting areas of research happening at the moment consider our local galaxies as if they were observed from a distance, something that can be done thanks to extensive surveys of stars in the Milky Way and deep imaging of other members of our Local Group of galaxies. Considering our own home in this way allows us to test the accuracy of techniques used to study the distant Universe – though in the case of the Milky Way, living in our object of study does make things slightly more complicated at times.

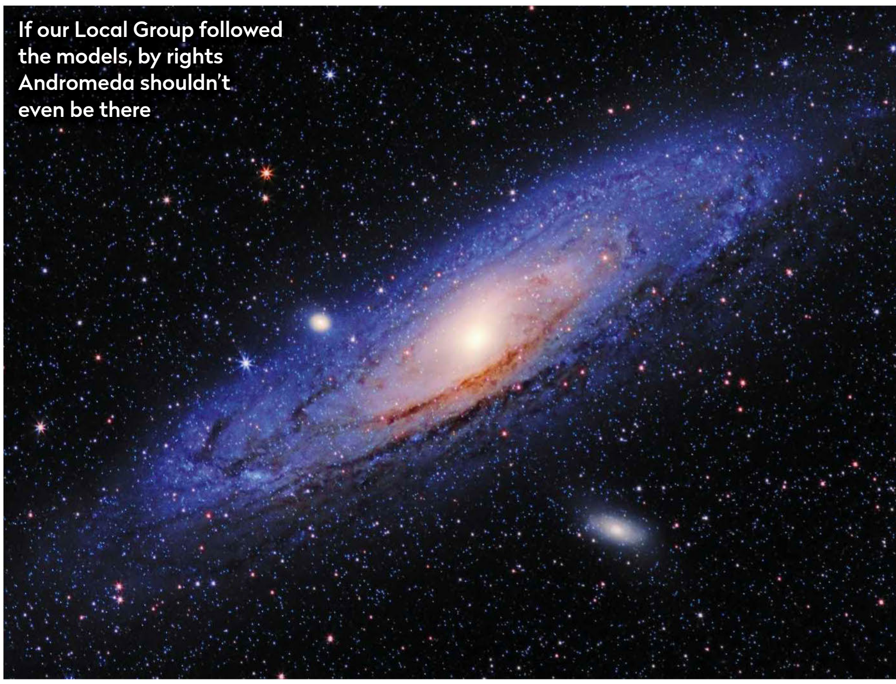
In this month's paper, Stacy McGaugh takes a close look at the relationships between how stuff moves in Local Group galaxies and the way that mass in those systems is distributed. This is crucial if you're interested in where to find the mysterious dark matter that most cosmologists believe makes up most of the mass in the cosmos. These measurements are even more important if, like McGaugh, rather than invoking the presence of dark matter to explain some of the oddities we observe in the Universe, our observations are best explained by modifying Newton's equations of gravity. Differences between our local galaxies and more distant neighbours may, he reckons, suggest problems with the dark matter model that we should pay attention to.

Things start off looking good for lovers of dark matter. One of the fundamental rules that seems to govern how galaxies are assembled is the Tully–Fisher relation, which says that if you know the mass of a spiral galaxy you can work out how fast the material in it should be rotating around the centre. Make these measurements for the Milky Way, Andromeda and a host of the small dwarfs that share the Local Group with us, and you find that they follow the same rule as distant galaxies. No signs of anything untoward here.

"Big denizens of the Local Group seem to have many more stars than we might otherwise expect for galaxies of their mass"

When we consider what the masses of the big galaxies are, problems appear. There are discrepancies between the mass of the Milky Way and Andromeda predicted by using the same sort of rules we use on distant galaxies, and what we observe by looking directly at their stars, or at how the material in their discs moves. Essentially, McGaugh points out that both of the big denizens of the Local Group seem to have many more stars than we might otherwise expect for galaxies of their mass. Put another way, something the size of the Local Group would typically have one large galaxy, the mass of the Milky Way – Andromeda is superfluous to requirements, and yet here it is.

McGaugh hints that this is another problem that dark matter can't solve. Others will point to the possibility that the particular history of Local Group's galaxies may have led them to have particularly efficient star formation, or perhaps that there is some subtlety to our studies of distant galaxies we have yet to understand. Either way, it's another reminder to look around us, and not always to seek answers in distant realms.



If our Local Group followed the models, by rights Andromeda shouldn't even be there

Chris Lintott was reading... *Local Group Galaxies from an External Perspective* by Stacy McGaugh **Read it online at: ui.adsabs.harvard.edu/abs/2023arXiv230500858M/abstract**

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT

June's episode of *The Sky at Night* looked at the booming UK spaceflight industry, but **Andrew Lawrence** warned of some of the consequences

▲ Vera Rubin Observatory, due online in 2024, will be scanning skies increasingly filled with satellite mega-constellations. Inset: NOIRLab's image of star Albireo, streaked with Starlink satellite trails

Space is booming. Satellites monitor the climate, connect us to the internet and help us to study the Universe. Someday soon we could get back to the Moon. Spaceflight is getting cheaper as new commercial companies build rockets and spacecraft, while dangling the promise of space tourism.

This is all very exciting, but at the same time, both scientists and industry workers are nervous about the potential dangers of uncontrolled proliferation. Streaks are increasingly spoiling astronomy images, while the threat of space advertising is rearing its head. The population of orbital debris could grow to pose unacceptable risks to spacecraft and leave space companies squabbling over real estate. The UK space industry's satellite-building capabilities – which cover all space applications from telecommunications to Earth observations to exploring the depths of the Universe – are internationally renowned and contribute huge amounts to the British economy every year. They are just as keen as any astronomer to make sure key orbits remain usable. Is there a way we can reach a sensible and fair compromise?

I've always been a space geek. I was a wee boy when Yuri Gagarin launched into orbit and I've been hooked ever since. Soon I was obsessed with stars and galaxies and quasars. As I emerged from my education into a PhD in X-ray astronomy, it was wonderful to see how my love for science and my love for space meshed together. Over the years, new and more wonderful astronomy space missions appeared – IRAS, the Hubble Space Telescope, XMM-Newton, Gaia – culminating in the astonishing James Webb Space Telescope, partly built where I now work, the Royal Observatory Edinburgh.

The fault in our stars

I've also used many ground-based telescopes and have specialised in working on big sky-survey projects. Right now, I am looking forward to the Vera Rubin Observatory, a huge telescope currently under construction in Chile that will scan the entire overhead sky every few days. Here in Edinburgh we're working with Belfast and Oxford to build a system to trawl through these images, looking for supernovae, flaring quasars and potential 'killer rocks'.

In late 2019, the warm glow I got from the synergy of astronomy and space was suddenly cooled by a splash of cold water – an image from the Dark Energy Survey, similar to those we hope for soon from Rubin,

Andrew Lawrence is the Regius Professor of Astronomy at the Royal Observatory Edinburgh and the author of *Losing the Sky*

was painted with bright streaks from Starlink satellites passing by. Soon, people all over the astronomical community were reporting other issues, including huge streaks in Hubble images. Over the last few years, the number of active satellites has more than doubled. By the end of the decade there could be tens or hundreds of thousands, outnumbering stars in the sky.

A series of workshops led by US astronomers studied the problem and eventually led to the creation of the Center for the Protection of the Dark and Quiet Sky, endorsed by the International Astronomical Union. In the last few years, I've concentrated on public awareness, writing a book called *Losing the Sky*, but also getting tangled up in legal and regulatory cases. I've become aware of the broader issues – space junk, commercial fairness, liability, space advertising – and see the issue as one of space environmentalism. The sky is perhaps the last pristine wilderness. We know that it is unrealistic to preserve it as completely untouched, and we positively want the benefits that can come from commercial space activity. But how do we balance the benefits against the damage and make space a happy playground for everybody? These are questions we're still looking for answers to.

Looking back: The Sky at Night

21 July 1984

On the 21 July 1984 episode of *The Sky at Night*, Patrick Moore was looking ahead to the arrival of Halley's Comet as it made its first return to the Solar System in 77 years. Though its closest approach wasn't expected until 1986, astronomers were already keeping an eye on the comet. It was first sighted on 16 October 1982 by the 200-inch Hale Telescope at Palomar Observatory, when it was no more than a faint dot on an image.

Wanting to make the most of the event, a group of astronomers called the International Halley Watch, made up of over 700 astronomers from 42 countries, had already begun rehearsing their observations. Between 25 and 31 March 1984, they focused on Comet P/Crommelin, a similar class of comet to Halley but significantly fainter – reaching a mere mag. +9.0 compared to Halley's +2.0 – that was passing along a very similar path across the night sky, making it a perfect trial run. Their observations highlighted several issues. For instance, JPL's Table Mountain Observatory struggled to see the comet against the light pollution coming from nearby Los Angeles, a problem the teams could then iron out ahead of time. Perhaps just as importantly, it also let the astronomers learn how to communicate and share data with such a wide group of people – a much more daunting prospect in the 1980s than it is today – leaving them fully prepared for the big event in two years' time.

▲ **Scientists scrambled to prepare for Halley's 1986 visit**

Is There Anybody Out There?

The Sky at Night follows Dr Douglas Vakoch on a visit to the UK. Vakoch believes we should be sending messages out into space to signal our existence to advanced alien civilisations. We meet the scientists working to find a language to communicate with aliens and investigate how we might get the message out there.

BBC Four, **10 July,** 10pm (first repeat will be on BBC Four, **13 July**, 7pm)
Check www.bbc.co.uk/skyatnight for more up-to-date information

▲ **Douglas Vakoch is president of the Messaging Extraterrestrial Intelligence (METI) programme**

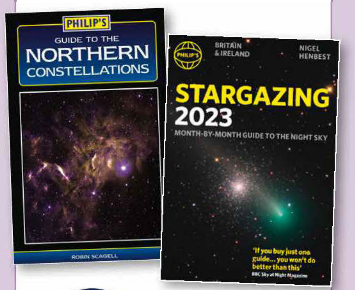
Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

MESSAGE OF THE MONTH

This month's top prize: two Philip's titles



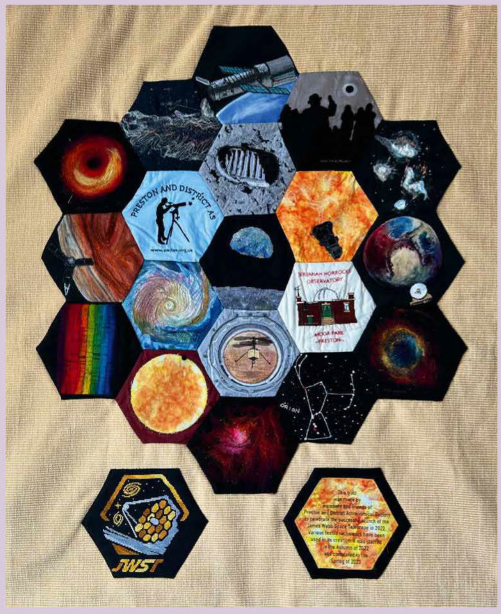
The 'Message of the Month' writer will receive a bundle of two top titles courtesy of astronomy publisher Philip's: Nigel Henbest's *Stargazing 2023* and Robin Scagell's *Guide to the Northern Constellations*

Winner's details will be passed on to Octopus Publishing to fulfil the prize

What a stitch up!

Much inspired by taking part in the Royal Astronomical Society Bicentennial Quilt project, the commemorative quilt-making initiative that marked the RAS's 200th anniversary in 2020, a few of us at Preston and District Astronomical Society decided to do our own to celebrate the launching of the James Webb Space Telescope. Using various stitching techniques, members and friends got busy during the long, wet, cloudy Lancashire nights to make this for the Science Fair at the University of Central Lancashire in May. It will eventually go on display at the Jeremiah Horrocks Observatory in Preston once the restoration work there is finished.
Clear skies!
Nicky Robertson, via email

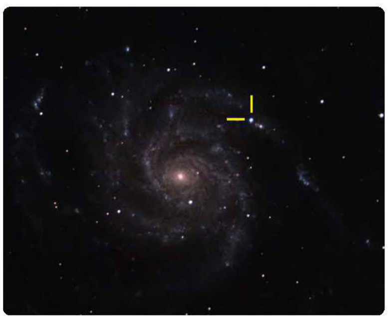
What a creative way to mark JWST's launch, Nicky. It must have taken many hours to stitch the detail on the 21 panels. Well done! ***– Ed.***

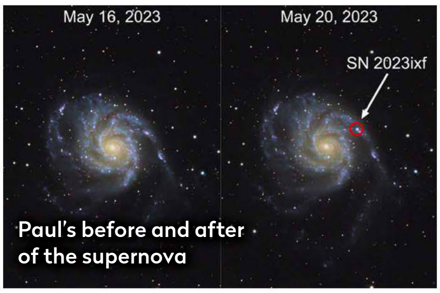


▲ **Nicky and friends at Preston and District Astronomical Society created this quilt as a textile tribute to JWST's iconic hexagonal mirrors**

Tweet

Chris Lee FRAS FBIS
@cpl43uk • 21 May
My imaging has been a bit quiet of late, trying to sort out some scope problems but managed to snap the bright Messier 101 supernova last night.
#M101 #SN2023ixf
@skyatnightmag





Paul's before and after of the supernova

Explosive stuff

I worked up a 'before and after' comparison of M101 and the new supernova, captured on 16 May (just before) and 20 May 2023 (very close to the start). My before image integrates 100x 3-minute exposures, and the after image integrates 120x 3-minute exposures. I processed and cropped both as similarly as I could. I'd be delighted if you found it useful.
Paul Macklin, via email

Libration spotted!

I recently found out about lunar libration, which lets us see slightly more of the Moon than the Earth-facing half because its orbit isn't a true circle and its axis of rotation is slightly tilted. I thought I'd compare two of my full Moon images, one from April and one from December, looking for differences around the Mare Crisium. When I checked both of them, I was delighted to see the December image showed more 'hidden' craters than the April image, east of Mare Crisium. I am happy to say I successfully caught lunar libration!
Stuart Hawk, via email

Photobomber

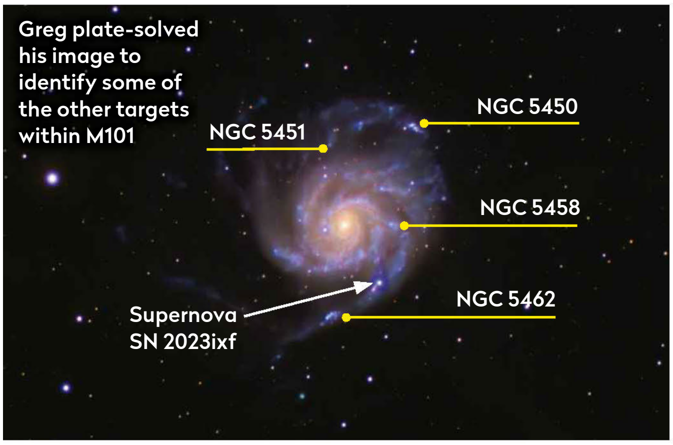
June's Message of the Month was about an image of Markarian's Chain with a mystery object, taken on 21 April

Another sighting of the mysterious object near Markarian's Chain

(Interactive, 'Mystery object', page 20). I photographed the same area on 19 April (above), using my Vaonis Vespera telescope, so thought I'd see if the same object was in my images. I think it is! I've compared mine with stock images and the object arrowed doesn't appear in them – whether it is asteroid 521 Brixia or asteroid 194 Prokne.
John Short, Whitburn, Tyne and Wear

Blast zone

I've been working on this shot (below) of the supernova in M101 over three nights, bringing together 4 hours and 45 minutes' worth of 7-minute frames. The supernova was very bright at the time and easy to see shining blue-white in the lower right of M101. There are lots of interesting targets around it too.
Greg Sanders, via email ▶



Greg plate-solved his image to identify some of the other targets within M101

ON FACEBOOK

WE ASKED: What are the best ways you know of to prove Earth isn't flat?

Keith Moseley If you can master simple geometry and trigonometry, al-Biruni's method is really neat for determining Earth's circumference.

Adrian O'Farrell The most glaringly obvious one: just go to Australia and see the Moon upside down.

Marc Hawil How many ways are there to prove it's flat?

Dougies Nick I can stand up straight. That proves Earth is a globe. If it was flat everyone would be pulled to the centre because of gravitational attraction.

Danny Cameron If you visit the equator, you get roughly 12 hours' daylight and 12 hours' night-time throughout the year. If you visit the northern latitudes like where I am in Scotland, during winter the Sun just rises above the horizon and sets a few hours later. In summer the opposite happens, so we get longer days and when the Sun does set, it just dips below the horizon and rises again a couple of hours later. These differences in the day/night cycle are proof the world isn't flat and is actually tilted on its axis.

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies

With **Steve Richards**

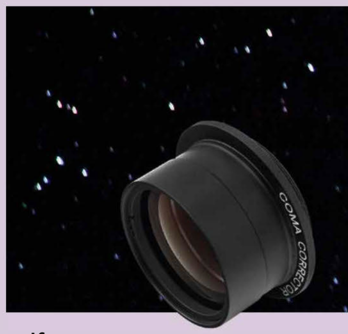
Email your queries to
scopedoctor@skyatnightmagazine.com

I have a Sky-Watcher 200PDS Newtonian telescope, a Sky-Watcher Coma Corrector and a Canon 650D DSLR. I've fitted the corrector with the recommended 54mm of back focus, but I'm still getting vignetting. Can you help?

RICHARD WHITE

Newtonian reflectors produce coma, elongated star shapes towards the edges of the field of view. The Sky-Watcher Coma Corrector is designed to improve these star shapes in images and, providing that you have the sensor-to-corrector lens distance set accurately (which, at 54mm, you have), it will do a good job. However, most Newtonians also suffer from some vignetting, which is an effect whereby the light intensity falls off towards the edges of the field of view and is most obvious in deep-sky images. As a result, stars of equal magnitude appear dimmer at the edges of the field than at the centre.

Vignetting is often caused by the telescope's secondary mirror being a little too small to fully illuminate larger sensors, but coma correctors can also cause the effect. There is little that can be done to stop the vignetting at source but fortunately, calibrating your images with flat calibration frames will resolve the issue in your captured images.



▲ If your coma corrector isn't fully effective, calibration may help

Steve's top tip

What is an off-axis guider (OAG)?

Although modern equatorial mounts can track celestial objects accurately, during long-exposure deep-sky imaging small tracking errors may produce trailed stars and smeared images. To avoid this, astro imagers use a second guide camera and autoguiding software to keep the mount tracking accurately over long periods. An off-axis guider (OAG) is a small device placed between the main camera and the telescope. It has a prism that picks off a small portion of light from outside the field of the main camera, directing it to the guide camera for analysis and mount correction by the autoguiding software.

Steve Richards is a keen astro imager and an astronomy equipment expert

BBC Sky at Night MAGAZINE

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Copyright query

If you process images taken by the James Webb or Hubble Space Telescopes (FITS files, for example), who owns the copyright of the final image? Does it remain as the property of the person or organisation who originally captured the data, or the person who has processed it and edited the data? It feels like a bit of a grey area, as anyone who processes FITS data does it their own way and adds their style to it.
Luke John Emmett, via email

Images taken by both of these space telescopes are in the public domain and individuals can use them for commercial and non-commercial purposes. However, they are also copyrighted by NASA and ESA, which means they must be credited, and their rights and restrictions in the images remain, even when adapted by individuals. Additionally, if an individual substantially alters the original image it might be considered a new work and eligible for its own copyright. **– *Ed.***

Instagram

astro.midnight • 22 May

Here is what I consider a unique version of M101, without the supernova. Unfortunately I wish I got it, but I was a few days early. Goodbye galaxy season, welcome back Milky Way season! #darkskies #space #nightsky @bbcskyatnightmag

CORRECTIONS

In the caption to the image in June 2023 issue's Bulletin ('Dark skies champion Bob Mizon passes away', page 14), the image shows Bob Mizon at the presentation of a Commission for Dark Skies personal award to Cranborne Chase AONB director Linda Nunn. Also, Cranborne Chase achieved Dark Sky status in 2019, not 2017.

Stephen Kirkman, the writer of June 2023's Field of View ('Fighting for the dark side', page 25), is a member of the West Yorkshire Astronomical Society, not Association as printed.

SOCIETY IN FOCUS

Airdrie Astronomical Association (AAA) was founded in 2009, when we were thrilled that Sir Patrick Moore accepted our invitation to be honorary president. We work closely with North Lanarkshire Council who own Carnegie Library: the smallest of Scotland's four public observatories is part of the library building.

Two of our members serve as honorary curators, trained in handling the clockwork-drive telescope. They share their knowledge and enthusiasm on open public viewing nights held weekly from November until the end of January.

We hold weekly meetings from September until May, where we learn about the latest in space exploration and astronomy from our Space News Team and enjoy presentations from members and invited speakers on subjects like gravitational waves or planet of the month. We also visit other clubs and societies, giving talks on topics such as the history of the observatory.

▲ Apollo 15 command module pilot Al Worden visited Airdrie Observatory in 2011

Looking back to 2010, 'Walk With Destiny' saw visits to the observatory by three Apollo astronauts: Dick Gordon, Al Worden and moonwalker Charlie Duke. They all signed our visitors' book, and so can you on paying a visit to 'Airdrie's best-kept secret'.
Aileen Malone, AAA Secretary
▶ **www.airdrieobservatory.com**

We pick the best live and virtual astronomy events and resources this month

WHAT'S ON

Bluedot Festival

Jodrell Bank, Cheshire, 20–23 July
The much-loved music and science festival returns. Science speakers include Maggie Aderin-Pocock, Chris Lintott and ESA's Libby Jackson, while music comes from Grace Jones, Pavement, Leftfield, Roisin Murphy and more. Day tickets from £42.90; weekend passes £229.25 including camping.
www.discoverthebluedot.com

How It Began

Lincoln Astronomical Society, Lincoln, 4 July, 7:30pm
Peter Rea from Cleethorpes & District Astronomical Society presents a talk on the origins of planetary exploration from 1961 to 1981. Non-members £5.
lincolnastronomy.org

Sun and Stars Celebration

Holworthy Farm, Brompton Regis, Somerset, 15 July, 2pm–late
A stargazing and solar observing event for all the family, hosted by local astronomer Jo Richardson FRAS. Accommodation is available at the farm itself. £18–£40. Booking essential.
holworthyfarm.co.uk

Exoplanets: Finding Earth 2.0

Royal Institution Theatre, London, 20 July, doors 6.30pm
Professor Richard Nelson of Queen Mary University of London and the International Astronomical Union outlines the latest discoveries and theories in exoplanet science. Tickets £16 (concessions £10; RI members £7).
www.rigb.org

UK SPACE AGENCY

PICK OF THE MONTH

▲ **Pop along to meet industry experts and hear about job opportunities in the space sector**

Space for Everyone UK tour

Various locations, June–September

The UK Space Agency is on the road this summer, travelling the UK to promote the space sector and showcase how it can improve life on Earth. *Space for Everyone: The Tour* will see a 22-metre replica of the LauncherOne rocket make its way around the country, accompanied by industry experts seeking to inspire the next generation of astronauts and engineers.

- Leicester: 29 June–3 July
- Bradford: 6–10 July
- Belfast: 20–24 July
- Aberdeen: 3–7 August
- Newcastle: 10–14 August
- Hull: 17–21 August
- Great Yarmouth: 24–28 August
- Hastings: 31 August–4 September

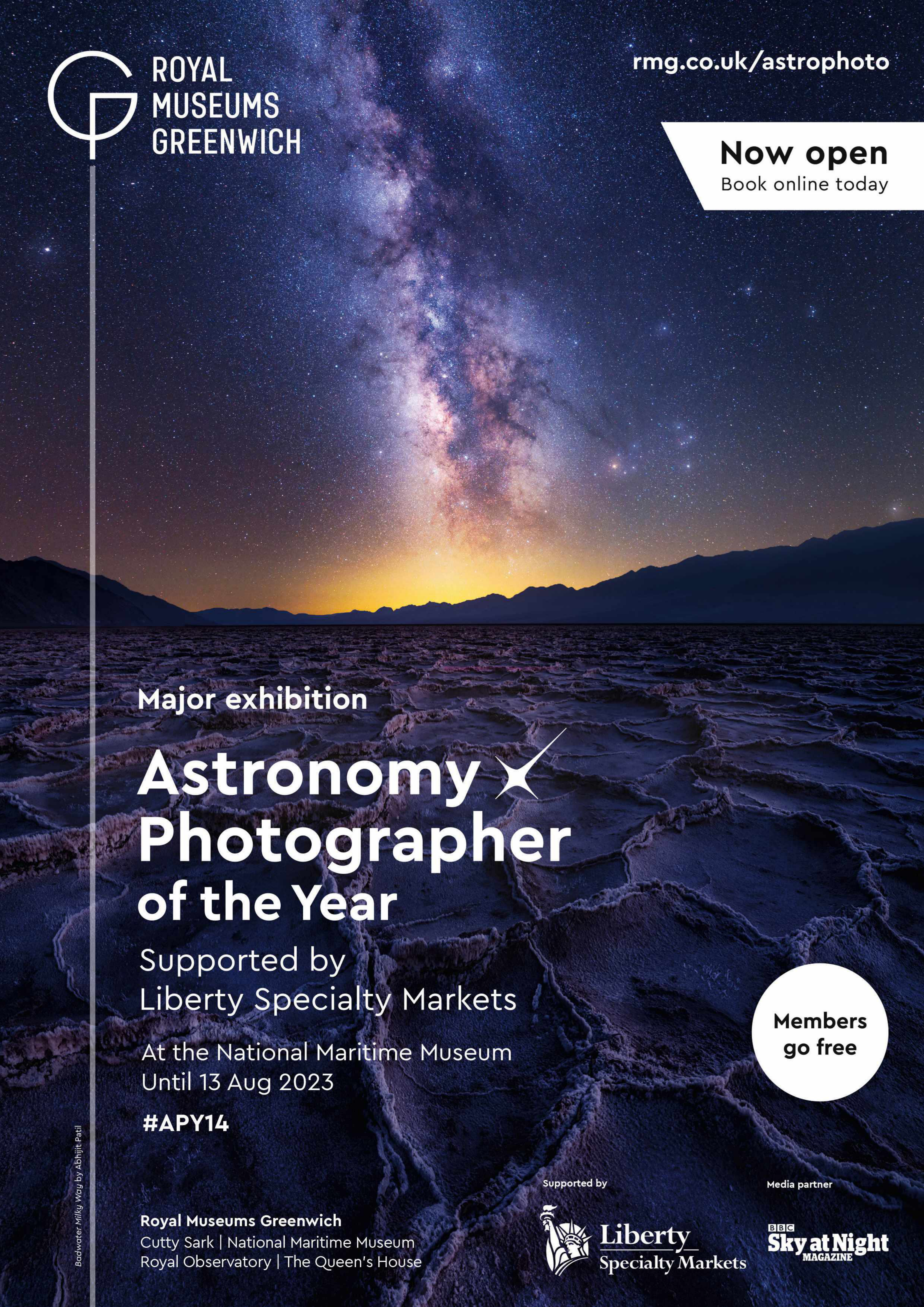
spaceperson.co.uk/rocket-tour

The Herschels in their own Words

Church Green Road, Bletchley, 28 July, 8pm
Royal Astronomical Society archivist and librarian Dr Sian Prosser, who has been digitising the journals of German astronomer Caroline Herschel, discusses the contributions she and her brother William made to the history of astronomy. Hosted by Milton Keynes Astronomical Society, admission is free and non-members are welcome.
mkas.org.uk

Family Evening

The Observatory Science Centre, Herstmonceux, East Sussex, 29 July, 5:30pm
Discover a wide range of science and astronomy exhibits and activities both indoor and outdoor at this family event that lasts from the afternoon into the evening. Tickets cost £18 for adults and £15 for kids, which includes admission to an out-of-this-world planetarium show and a bag of French fries. The cafe and catering van will also be open.
www.the-observatory.org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Astronomy Photographer of the Year
Supported by Liberty Specialty Markets
At the National Maritime Museum
Until 13 Aug 2023
#APY14
Members go free
Badwater Milky Way by Abhijit Patil
Royal Museums Greenwich
Cutty Sark | National Maritime Museum
Royal Observatory | The Queen's House
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BBC Sky at Night MAGAZINE

FIELD OF VIEW

It's time that space had a female face

Equality for women will make a stronger space sector, says **Gabriella Goddard**

Executive coach and leadership expert **Gabriella Goddard** is CEO and coaching director of the Space Leadership Academy and founder of the Brainsparker app

As a woman in the space sector, I take great pride in smoothing the path for leadership and innovation – although I find the lack of gender diversity within the industry still quite concerning. Despite an improvement in the number of women entering the space industry over the past 20 years, particularly at a senior level, it remains a male-dominated field. To this day, only 11 per cent of all people that have been to space are women; and beyond that the representation of women in STEM, a vital talent pipeline for the sector, sits at only 22 per cent globally.

Increased commercialisation and funding are paving the way to revolutionise our ability to journey deeper into space. Despite this momentum, the UN reports only one in five space industry workers are women. The roots of the space sector lie within the government and the military, which means the culture remains very traditional: male-dominated and highly technical. Limit to access breeds limit to success, and the breadth of skills within the sector is curbed if the talents and capabilities that women can offer aren't incorporated.

Space is shaping the future of humanity, and so the failure to represent women in the space industry denies everyone. We cannot discourage women from wanting to take part in decisions that stand to shape their future; instead we should work to break down the barriers to access for those wanting to enter the space industry and STEM disciplines like engineering and technology.

In my own experience, it can be intimidating at times to be confronted with challenges around being taken seriously, pitching to investors and securing funding. I have learned to find strength in diversity and I firmly believe we can drive progress to overcome these challenges through collaboration, inclusivity and support.

There are vibrant female entrepreneurs making strides across the industry, and their expertise and diversity of thought should be celebrated. It's encouraging to see initiatives like the UK Space Agency Accelerator taking an active role in recruiting female entrepreneurs onto their programmes, which are designed to give entrepreneurs the mentoring and commercial support they need to grow a sustainable space business.

Representation of women in the space industry is vital in demonstrating to young women and children that space exploration is not just reserved for men, but for all those who are passionate about it. The space industry needs to attract girls from an early age, encouraging more children and young people to study aerospace engineering, for example, and encouraging those already in the industry to become senior leaders, as well as attracting people from outside the industry who can contribute to innovation and growth. While progress has been made in the last 20 years, this is an ongoing issue prompting continued investment in support and resources for women.

There is great promise in the UK space industry: it is highly collaborative and integrational in the way lots of other industries aren't. We should use this vantage point to encourage women to be part of the ground-breaking projects that will make an impact for future generations.

SARAH MAXWELL/FOLIO

A year with JWST

To celebrate JWST's first year of operation, **Jenny Winder** takes a look at some of the landmark scientific discoveries it has made over the last 12 months

NASA/ESA/CSA/STSCI/WEBB ERO PRODUCTION TEAM, ALEX-MIT/ISTOCK/GETTY IMAGES

With a primary mirror measuring 6.6m across made from 18 gold-coated segments, the James Webb Space Telescope (JWST) is a beautiful instrument in its own right. But stunning as this technological marvel might be, it's nothing compared to the remarkable data it has unearthed over the last year.

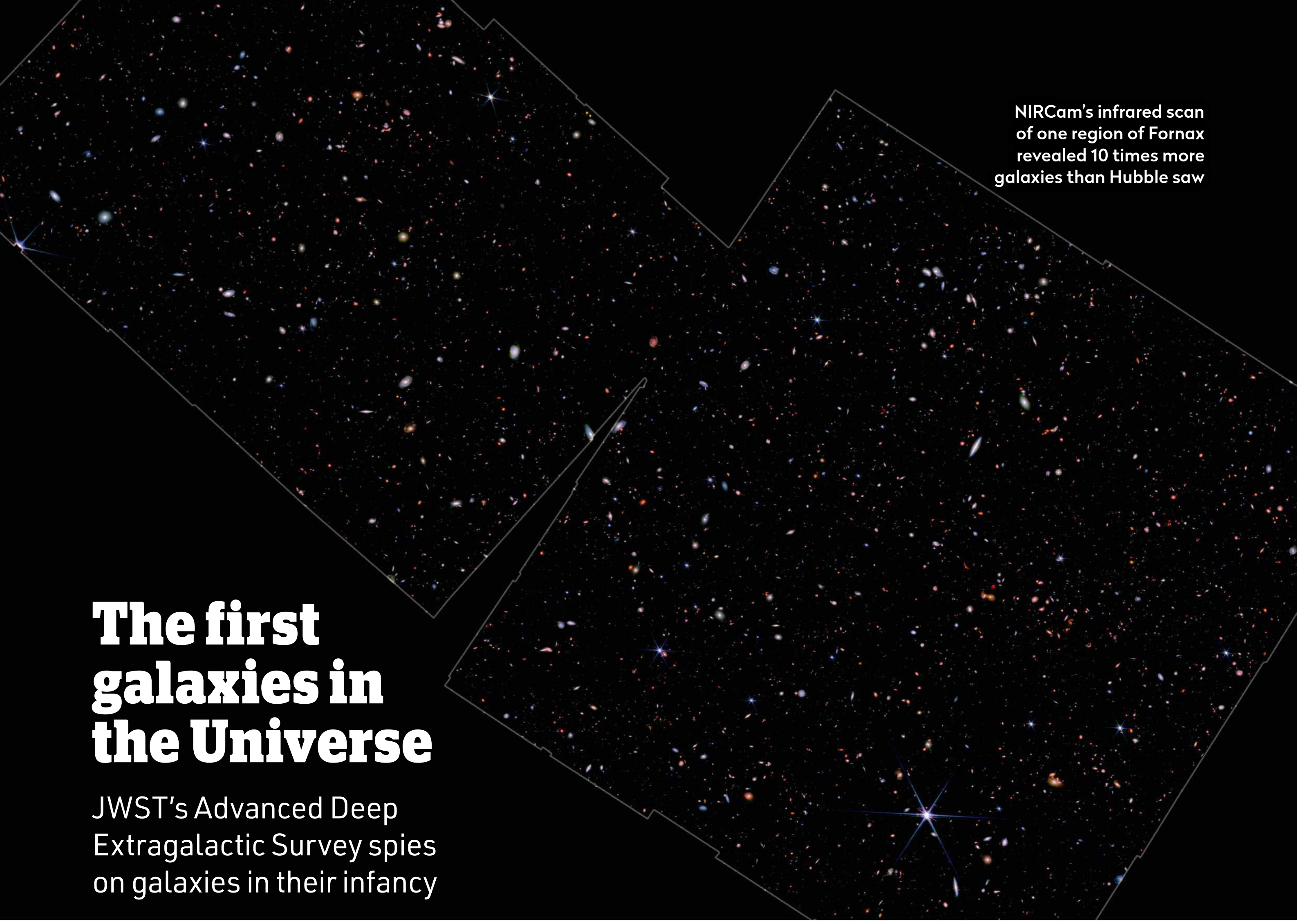
JWST launched on 25 December 2021, reaching its operational orbit at the second Lagrange point, 1.5 million kilometres from Earth, a month later. After a few more months calibrating its instruments, it was finally ready to turn its gaze on the Universe.

JWST has been tasked with investigating four main science goals: the early Universe and the first galaxies; the growth and evolution of galaxies over time; the lifecycle of stars; and the study of other worlds.

The new telescope is uniquely suited to investigating these goals as it observes infrared wavelengths. This light can pass through clouds of dust and gas, and reveal warm objects that do not shine in visible wavelengths, meaning it can peer into corners of the Universe previously hidden from view.

JWST began returning its first remarkable scientific findings in July 2022. Here we look back at some of the milestones it has achieved during its first year. ▶

Never-before-seen generations of newborn stars in the Tarantula Nebula provide a brand new window into the Universe's past – just one of the revelations in JWST's mind-blowing debut year



NIRCam's infrared scan of one region of Fornax revealed 10 times more galaxies than Hubble saw

The first galaxies in the Universe

JWST's Advanced Deep Extragalactic Survey spies on galaxies in their infancy

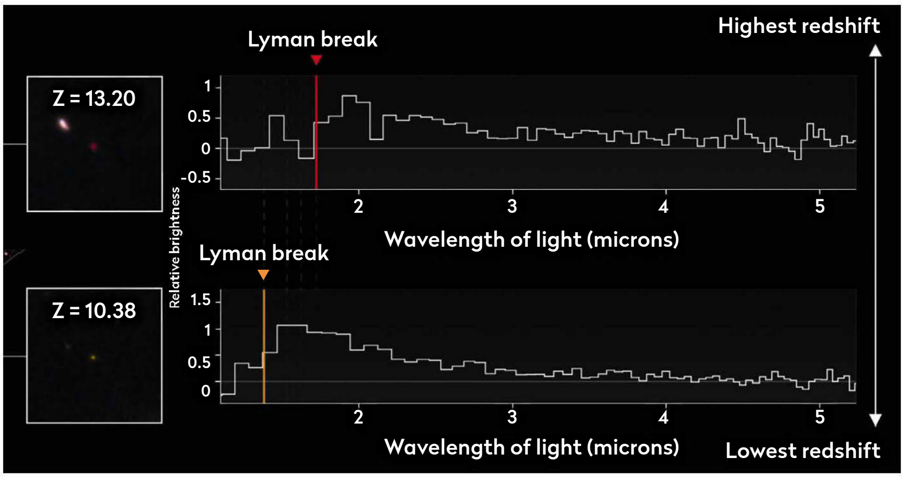
▶ One key part of JWST's mission will be to use its infrared eyes to peer through the dust and gas to the earliest eras of the Universe. Here it will help discover how the first stars and galaxies formed, as well as uncover fresh evidence for dark matter.

JWST's Advanced Deep Extragalactic Survey (JADES) has been allocated a month of JWST's observing time, spread out over two years, and takes advantage of the telescope's unprecedented sensitivity to investigate the earliest galaxies in greater detail than ever before.

In December 2022, JWST discovered the most distant, and therefore earliest, galaxies ever found – at least up to that point. The light from these galaxies set out when our Universe was just two per cent of its current age, and has taken the last 13.4 billion years to reach us.

JADES focused JWST on the same patch of sky as Hubble's Ultra Deep Field, located in the Fornax Cluster. While Hubble found an impressive 10,000 galaxies in the region, JWST's image is 15 times larger, and contains a staggering 100,000 galaxies.

Astronomers are still sifting through this deluge, looking for the most distant galaxies among them. One 'easy' way to pick out distant candidates is to use the fact that hydrogen gas absorbs almost all light at wavelengths shorter than 91nm, called the Lyman limit. Since galaxies are filled with hydrogen, this creates a sharp 'step' in their ultraviolet and X-ray emissions. However, as light travels through space it is stretched (or redshifted) due to the expansion of the Universe. The longer it travels, the more it stretches, until this step in emissions moves into the visible range. Astronomers can use the position of this 'Lyman break', to work out how far away a galaxy is.



▲ Two of the faintest, most distant galaxies revealed by the 'Lyman break' in the spectra

For 28 hours over three days, JWST collected the faintest infrared spectra ever taken from 250 candidate galaxies, revealing the precise position of the Lyman break in each galaxy. This confirmed that four of the galaxies had a redshift above 10, setting new distance records, including two with redshifts of 13.

JADES will now study Hubble's Deep Field, a small region in Ursa Major, before returning to the Ultra Deep Field, so we can expect many more 'most distant galaxies' to be confirmed in the future.

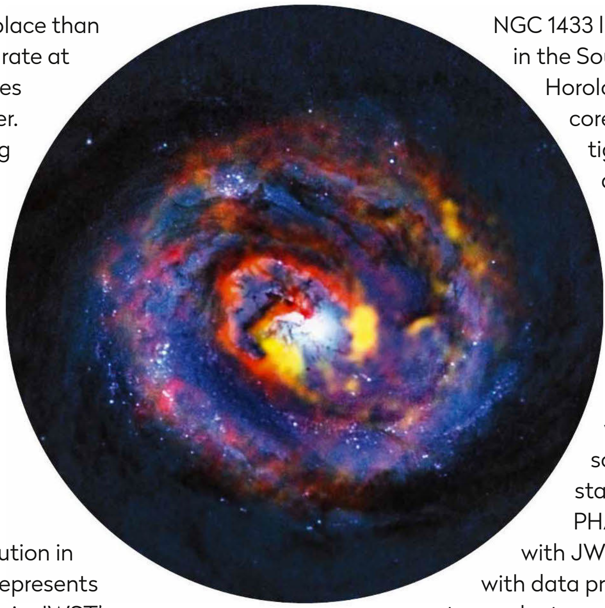
NASA/ESA/CSA/M. ZAMANI (ESA/WEBB), NASA/ESA/CSA/JOSEPH DEPASQUALE (STSCI), ALMA (ESO/NAOJ/NRAO)/NASA/ESA/F. COMBES, NASA/ESA/CSA/AND J. LEE (NOIRLAB) A. PAGAN (STSCI)

Gracefully growing galaxies

A burst of star formation drove the evolution of galaxies in the early Universe

The early Universe was a far busier place than it is today. Ten billion years ago, the rate at which stars burst into life and galaxies crashed together was 10 times higher. JWST aims to investigate the driving force behind this activity – as well as its sharp decline – by tracking galaxies over time to see how they have evolved. JWST is able to study areas previously hidden from view and begin to reveal how the formation of stars – some of the smallest objects in the Universe, cosmologically speaking – can influence the structure and evolution of some galaxies, some of the largest objects in the Universe.

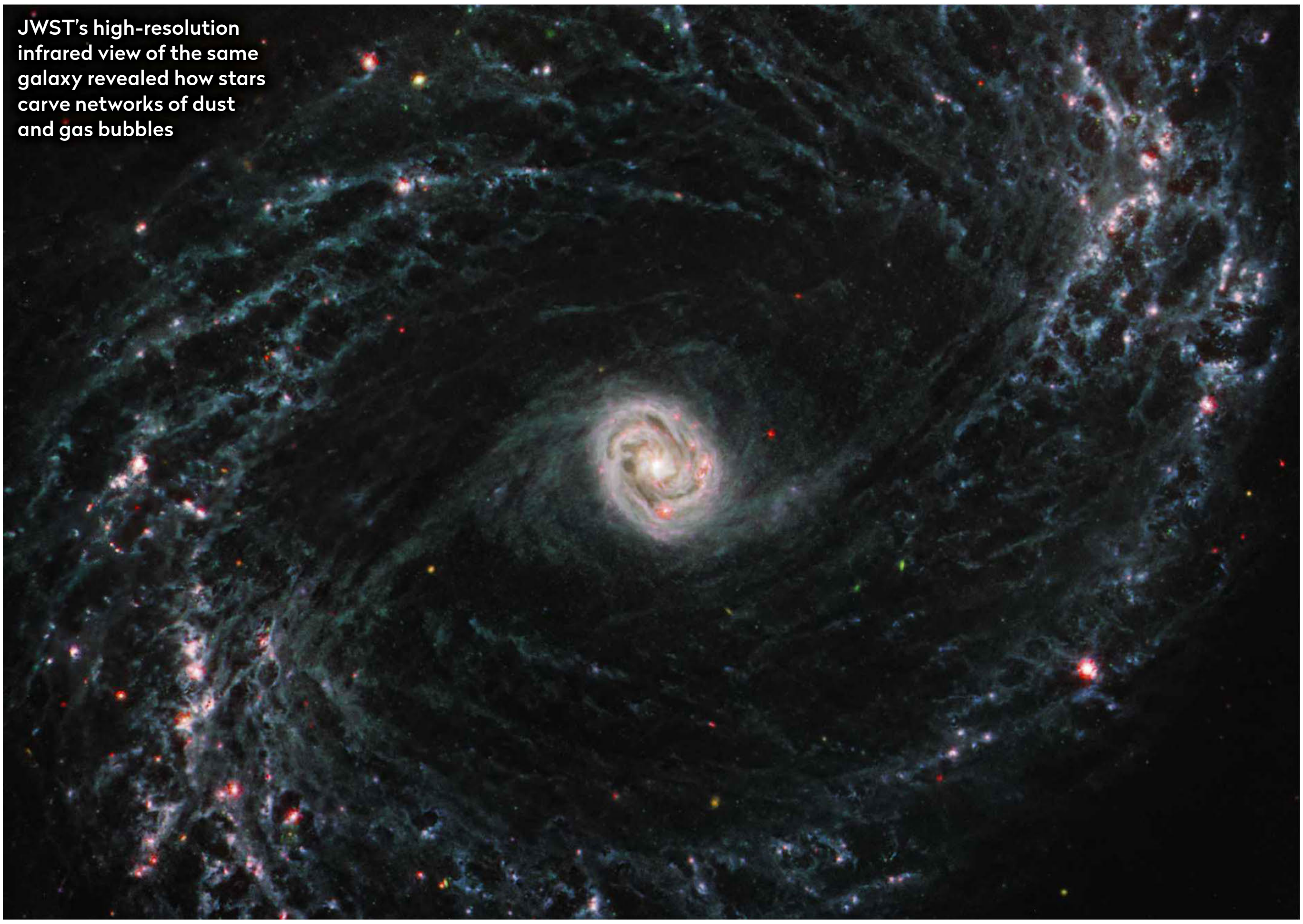
The Physics at High Angular resolution in Nearby Galaxies Survey (PHANGS) represents the largest survey of nearby galaxies in JWST's first year of science. Its international team of 100 researchers are investigating 19 diverse spiral galaxies and have already made observations of five of their targets, including the spiral galaxy, NGC 1433.



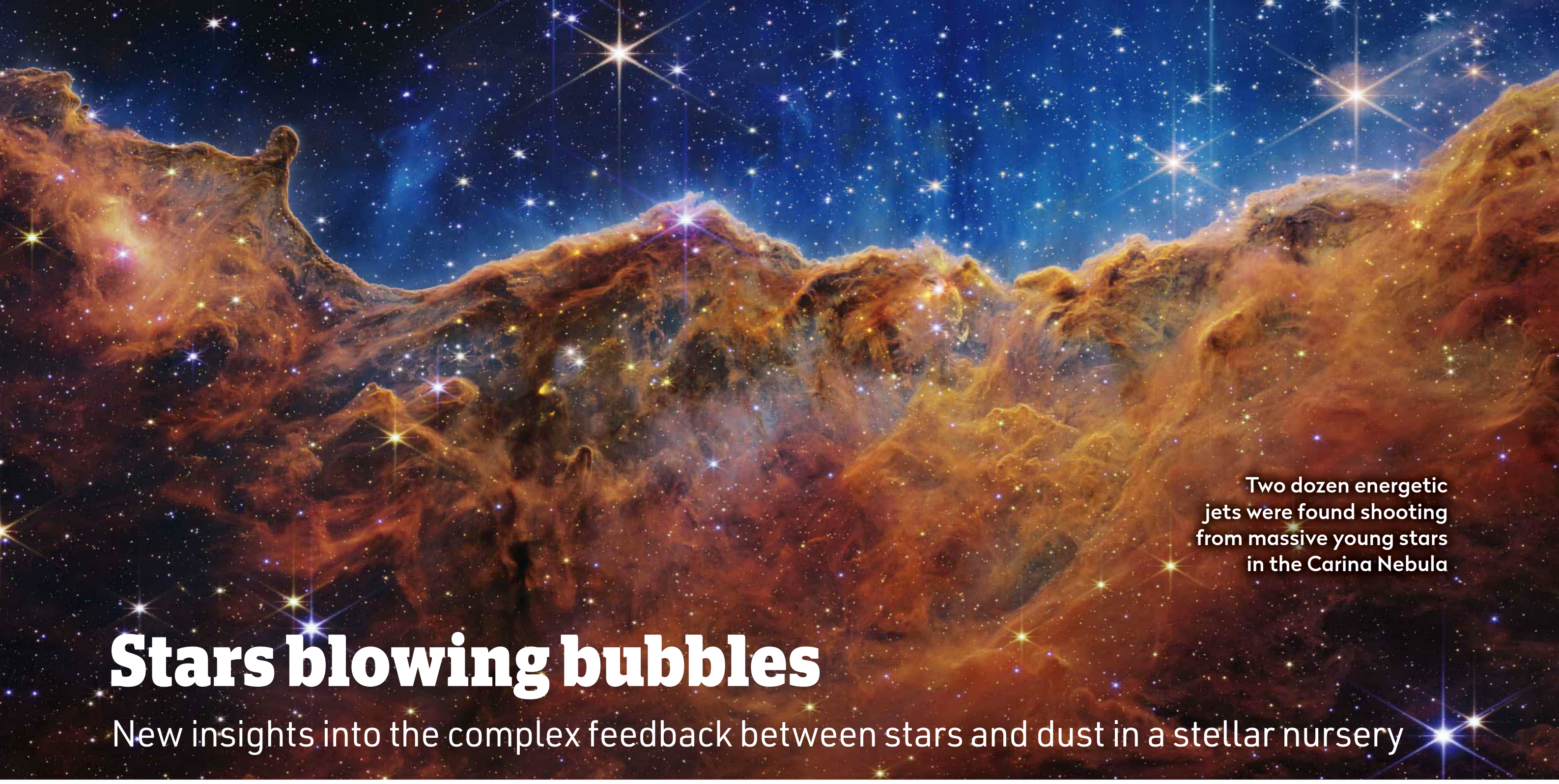
▲ A Hubble and ALMA image of NGC 1433, one of 19 spiral galaxies in the PHANGS study

NGC 1433 lies 46 million lightyears from Earth in the Southern Hemisphere constellation of Horologium. The galaxy has a tight, bright core that features a unique double ring of tightly wrapped spiral arms, wound into an oval structure along its central bar.

JWST's sensitivity to infrared has revealed a network of cavities and huge bubbles of gas lining the galaxy's spiral arms, which had previously been hidden by clouds of dust in the galaxy. The cavities are formed by young stars interacting with the gas surrounding them, and so will help give key insights into how star formation shapes growing galaxies. PHANGS will continue to survey galaxies with JWST, and combine these observations with data previously taken by other telescopes to conduct a complete census of star formation in nearby galaxies, beyond the Local Group, to reveal how star formation gave rise to, or impeded, the formation of the next generation of stars at earlier stages in the Universe's evolution. ▶



JWST's high-resolution infrared view of the same galaxy revealed how stars carve networks of dust and gas bubbles



Two dozen energetic jets were found shooting from massive young stars in the Carina Nebula

Stars blowing bubbles

New insights into the complex feedback between stars and dust in a stellar nursery

▶ Stars begin their lives in dense clouds of obscuring dust and gas, but JWST's high-resolution infrared capabilities are able to pierce through this and reveal stars growing in their cosmic nurseries.

One of the first images released by JWST back in July 2022 was of NGC 3372, a young star-forming region 7,600 lightyears away, in the northwest corner of the Carina Nebula, NGC 3372.

JWST's infrared instruments revealed the edge of a gigantic gaseous cavity – a huge bubble created by the intense radiation and stellar winds from nearby massive, hot, young stars, dubbed the Cosmic Cliffs.

As the ionised rim of the bubble pushes into the gas and dust of the nebula, the change in pressure can cause either a boom or bust – material either collapses to form new stars or erodes away, preventing star formation. Dense clouds form more massive stars, which in turn drives the gas into voids and denser regions where lower-mass stars form.

As the growing stars pull material in, high-velocity jets of gas and dust stream from the stars' poles. These jets only appear briefly, during periods of active accretion, but astronomers have still managed to find 24 such flows. Instead of a steady stream, these flows are chains of dense, fast-moving clumps, indicating that accretion occurs in a series of short, powerful bursts.

Monitoring these outflows allows astronomers to estimate how fast they move, how much mass they carry and their effect on growing stars and planets.

Dissecting distant planetary atmospheres

The telescope is unpicking the chemical profiles of alien worlds

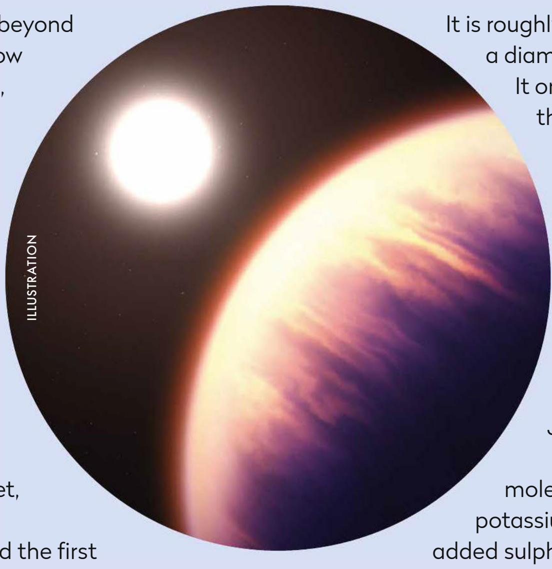
We now know of thousands of planets beyond our Solar System, but while we may know the size, mass and orbit of these worlds, understanding of the atmospheres above them has proved elusive. Whether a 'hot Jupiter' or a small, rocky planet, knowing what is above the world gives key insights into their composition, formation and evolution. However, JWST's sensitive instruments can distinguish a far wider range of atmospheric molecules than ever before.

In August 2022, JWST achieved a hat-trick of firsts when it made its first science observation of an exoplanet, where it also obtained the first detailed exoplanet spectrum in near-infrared and the first indisputable evidence for carbon dioxide in an exoplanet's atmosphere.

The exoplanet in question was WASP-39b, a hot gas giant 700 lightyears away, discovered in 2011. It is roughly the same mass as Saturn, but with a diameter 1.3 times greater than Jupiter. It orbits its parent star eight times closer than Mercury orbits the Sun, giving it a surface temperature of 900˚ Celsius.

JWST watched the planet as it passed in front of its star and detected the starlight that filtered through the planet's atmosphere. Different molecules in the atmosphere absorbed certain wavelengths of light, leaving 'fingerprints' in the star's spectra that JWST was able to pick up.

Previous observations found isolated molecules of water vapour, sodium and potassium. JWST's sensitivity to infrared added sulphur dioxide, carbon monoxide and carbon dioxide to the list. The latter of these could be an important indicator of a planet's potential to support life, showcasing JWST's role in the search for habitable, Earth-like worlds.



▲ Gas giant WASP-39b was found to have water, sulphur dioxide, carbon monoxide, sodium and carbon dioxide

NASA/ESA/CSA/STSCI, NASA/ESA/CSA/J. OLMSTED (STSCI), NASA/ESA/CSA AND B. HOLLER AND J. STANSBERRY (STSCI), NASA/ESA/JUPITER ERS TEAM; IMAGE PROCESSING BY RICARDO HUESO (UPV/EHU) AND JUDY SCHMIDT

A fresh look at Jupiter

Infrared images give a new look to our Solar System's largest planet

JWST will also take a look a little closer to home at the planets within our own Solar System, and it has already turned its eyes on several of our planetary neighbours. As planets only shine by reflecting starlight, they do not emit much energy or visible light, yet they still radiate in infrared, making them ripe candidates for JWST.

JWST's near- and mid-infrared sensitivity can look through the atmosphere to different depths, highlighting the evolution of cloud structures and storms in finer detail than ever before.

Three specialised infrared filters on JWST's near-infrared camera, NIRCam, turned their sights on Jupiter, the largest planet in our Solar System. Each filter is assigned a colour – red, yellow/green or blue – to allow astronomers to transpose the invisible infrared into something we can see. The resulting image is a composite, as Jupiter's fast rotation (once every 10 hours) makes aligning the separate images a challenge since features move during the time it takes to capture the images.

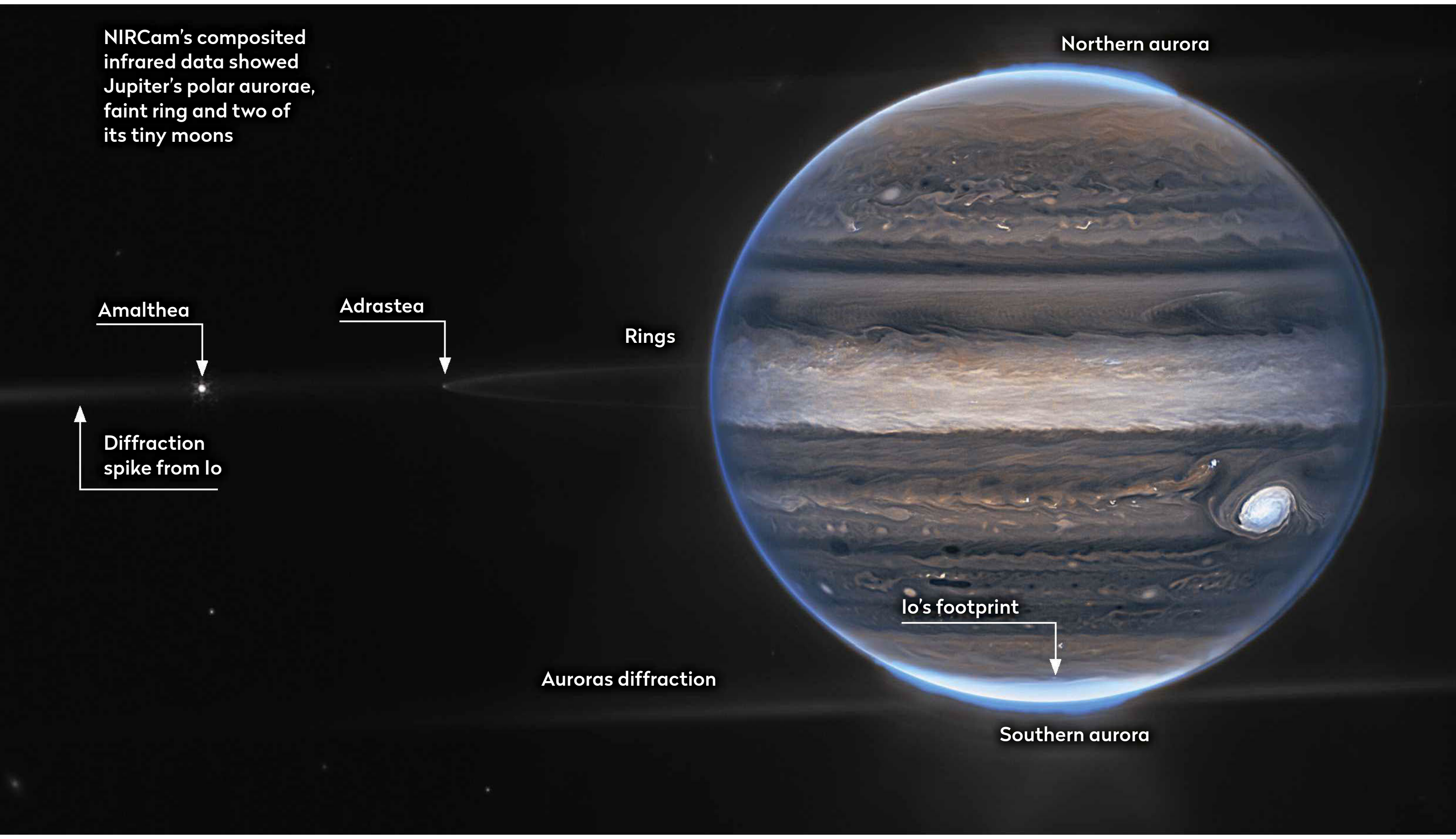
Closer to home, JWST turned its powerful infrared eye to Jupiter

While the image below shows aurorae high above both of Jupiter's poles, each filter highlights a different aspect of the planet's atmosphere. The red filter highlights the lower clouds and upper hazes. The yellow/green filter also shows hazes around the poles, while the blue filter shows up the deeper main cloud. The brightness of features represents their altitude. Some clouds, and the famous Great Red Spot, are dazzling white, due to their very high-altitude cloud tops of condensed storms reflecting a lot of sunlight. The higher-altitude clouds of the bands north of the planet's equator, meanwhile, appear dark.

It's not just the planet itself the telescope is looking at. A widefield view shows Jupiter's faint ring and two of its tiny moons, Amalthea and Adrastea. In future, JWST will turn towards Jupiter's largest moon, Ganymede, to study the potential ocean hidden beneath its surface, and search for previously undetected volcanoes on Io.

Jenny Winder is a freelance science writer, astronomer and broadcaster

NIRCam's composited infrared data showed Jupiter's polar aurorae, faint ring and two of its tiny moons



With solar maximum on its way, it's an exciting time to start recording the Sun's dynamic surface features

ALL PICTURES: PETE LAWRENCE

CAUTION
Never observe or image the Sun with the naked eye or any unfiltered optical instrument

Seeing THE SUN in white light

Pete Lawrence is your guide to making safe visual observations of our nearest star this summer

Observing the Sun in white light is rewarding and relatively simple to do. It's also inexpensive, especially if you already have a telescope; all you need is a white-light solar filter.

There are many different ways to make a record of white-light solar activity, including simple counts of surface features, full-disc images, generic sunspot classifications and detailed classifications. In this article we'll guide you through solar observation, from the basics to performing detailed, daily sunspot classifications. Your observations will really help solar science, and don't forget that this is a unique opportunity to study a star close up!

First, though, we have to address the issue of solar safety. Concentrating the Sun's energy through a lens or with the concave mirror of a reflecting telescope raises it to potentially dangerous levels, so never look through or point any unfiltered telescope directly at the Sun. This includes small finder telescopes too, as apart from the obvious fire risk, there's a good chance you'll burn out their crosshairs. We'd recommend capping, filtering or removing finderscopes just to be sure.

A certified white-light solar safety filter fitted

Safety first: fit a full-aperture safety filter before pointing your scope towards the Sun

over the front, open end of the telescope reduces radiation levels, making the Sun suitable for direct observation. Ready-made full-aperture solar filters can be ordered for your scope size or you can buy certified solar safety film at relatively low cost and make your own full-aperture filter. If you have a large scope, larger rolls of film are available or an alternative is to make an offset aperture filter. This is a large piece of opaque card that covers the full ▶


Faculae are bright areas associated with spotty and spotless active regions, best seen in white light near the edge of the solar disc

▶ scope aperture with a smaller circular opening cut in it, which is covered with the solar filter. If your scope has a secondary obstruction, the opening needs to be offset from the centre. Always make sure to check the filter before you fit it. If it's ripped or lets light through, discard it and buy or make another.

Get to know the features

With the filter fitted to the scope, it's time to turn it towards the Sun. The best way to do this is to look at the shadow of the scope on the ground, adjusting the scope's position until the shadow size is at its smallest. If you're using a neutral density (ND) 5.0 or higher film, you can view the Sun through the eyepiece. Most DIY filter film is ND 5.0, although there are speciality versions like ND 3.8, targeted at imagers, that let more light through and are unsuitable for visual use.

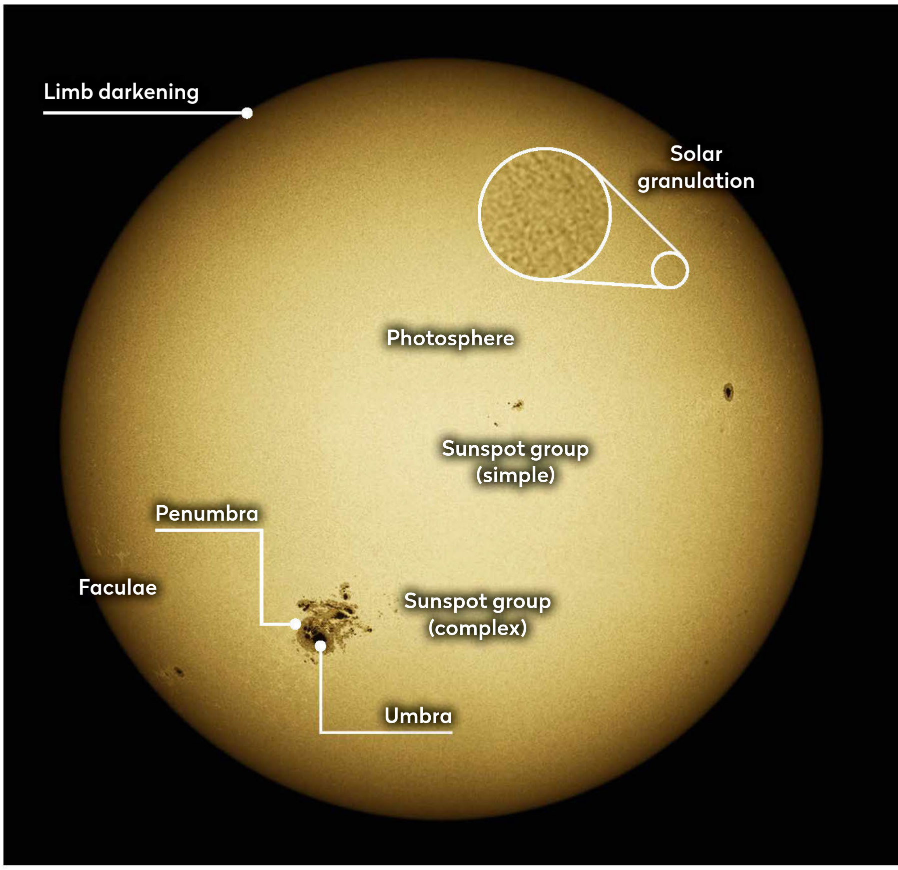
A white-light filter effectively dims the Sun's output to make it suitable for direct viewing. When you look at the Sun through a white-light filter, you're looking at its visible surface or 'photosphere' – literally 'sphere of light'. This isn't uniform in brightness, appearing dimmer towards the edge of the Sun's disc, a phenomenon called 'limb darkening'. Through a 150mm or larger scope with good seeing, the photosphere appears granular. This is because you're looking down on the top of a myriad of convective cells. This rice-paper-like appearance is known as 'solar granulation'.

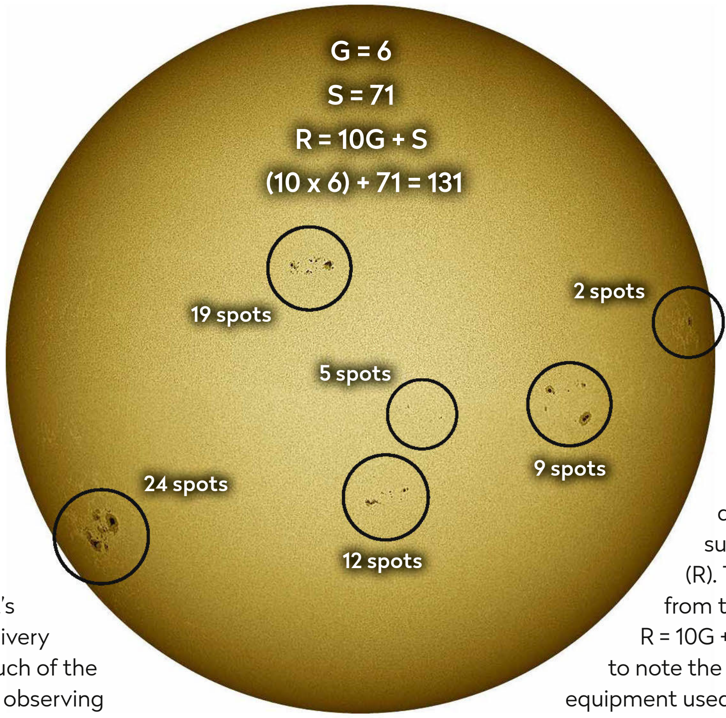
If the Sun is active, you may see dark patches on the photosphere, which are sunspots. These can appear as tiny single pores or as larger dark regions (umbrae) surrounded by lighter material (penumbrae). Complex regions containing many clustered spots are known as sunspot groups or active regions. Some have lots of individual spots, some have large areas of penumbra which contain many umbral spots.

Lighter patches may also be seen around active regions. These are called faculae and are hard to see near the centre of the photosphere but stand out well near the edge in the limb-darkened zone.

You may also see 'light bridges' within large complex spots – a brightening between umbral regions that represents an area where convection is reasserting itself. Such a feature is typical of a sunspot group on the verge of breaking up.

▼ **Features visible on the Sun's photosphere; a 150mm filtered scope is required to see solar granulation**





▶ **A simple sum of the groups (G) and spots (S) you find will tell you your relative sunspot number (R)**

When trying to see these features, atmospheric instability or seeing will affect the view. Unlike night-time seeing, it's the Sun's energy delivery which is creating much of the instability. Different observing sites tend to have different 'sweet-spot' times when seeing is most stable. Typically, this occurs in the late morning or late afternoon, the latter tending to be the least stable. A specific solar seeing scale exists for noting these conditions (see below right).

Counting spots

You don't need to be an expert to start collecting solar data. The easiest technique is to simply count how many sunspots are visible. A slightly more refined method than this involves a count of how many individual spots you can see (S) and how many groups are present (G). A group is typically defined when its spots lie within a 10˚ span of heliographic longitude and appear at roughly the same heliographic latitude. Estimating this can be a black art at first, but it soon becomes second nature. Calculating the longitude and latitude values can be done using speciality software (see Location, location, location, page 38) or was traditionally calculated using pre-printed gridded sheets called Stonyhurst discs.

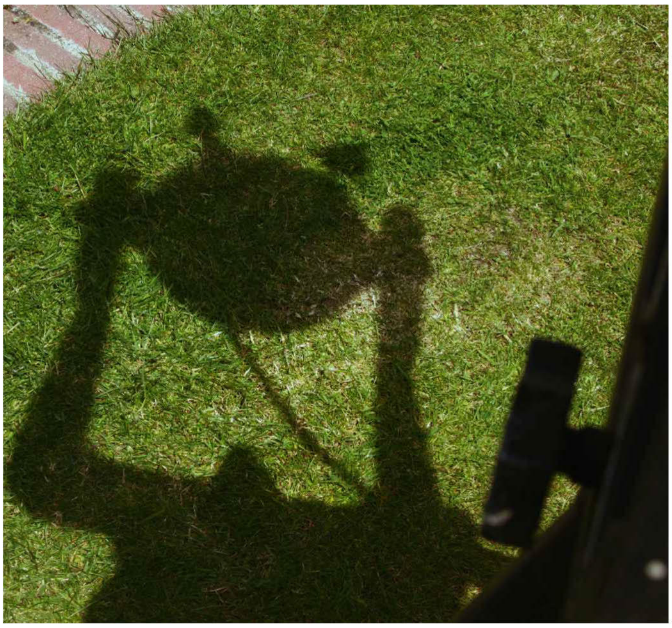
Once you've counted your daily S and G values, you can derive your relative sunspot number (R). This is calculated from the simple formula R = 10G + S. Don't forget to note the date, time, equipment used, an estimate of solar seeing (table below), your name and location to validate the observation. You can send your results to **britastro.org/solar**. If you're new to solar observing, it's advisable to get used to how the Sun 'works' by doing the daily (or as near to daily as possible) spot and group count, to determine your relative sunspot number as described.

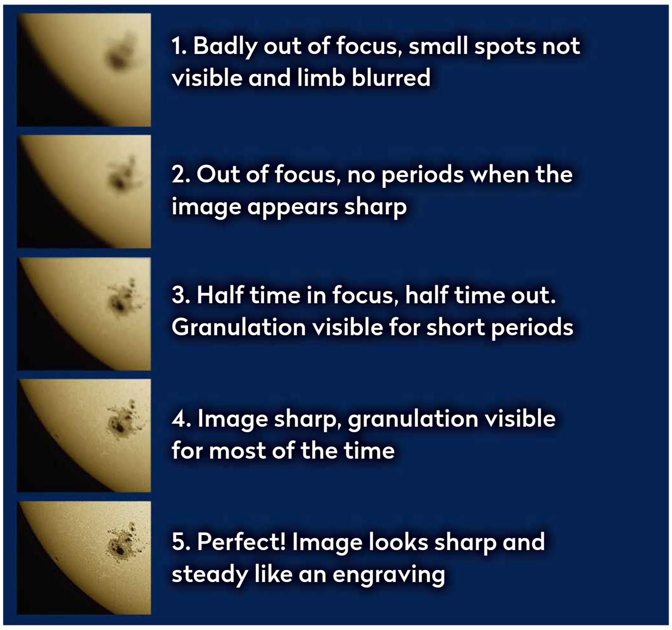
When you feel confident, consider moving to a higher level of observation by attempting to classify each active region. The way to do this is to follow the modified Zürich classification scheme. We've shown the main classes in table 1 on page 39, categorised from A through to H.

Additional refinement comes from using the McIntosh classification scheme, which builds on the Zürich classification. The McIntosh classification uses three values: Z, p and x, Z being the modified Zürich classification shown on page 39. The second component is p, which is used for classifying the largest spot in a group. The final component x describes the spottiness or degree of compactness of the group's interior. See page 39 for examples ▶

▼ Below left: to point your scope, adjust its position until its shadow on the ground is minimised

Below right: solar seeing scale from 1 (poor) to 5 (pristine conditions for viewing and imaging)





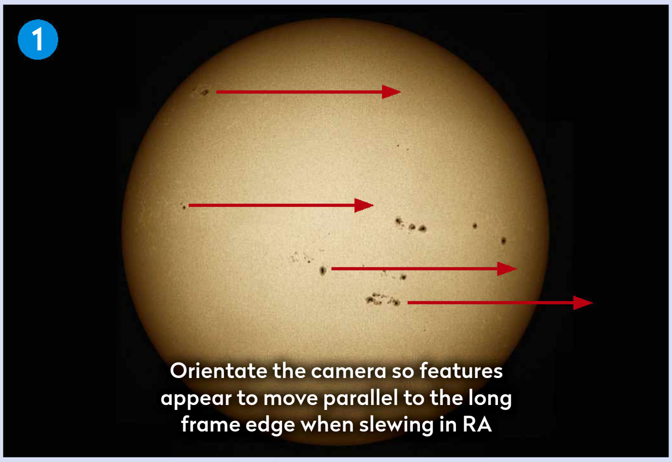
Location, location, location

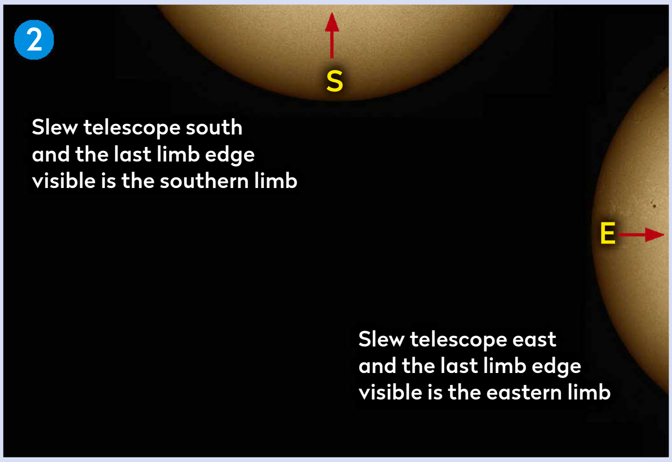
How to work out the position of a photospheric feature on the solar disc

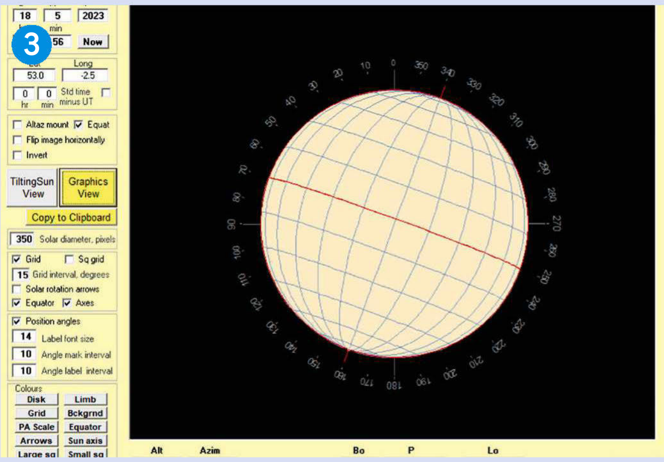
A feature's position on the Sun's disc is given by a coordinate system similar to Earth's latitude and longitude, known as heliographic latitude and longitude. Programs like TiltingSun (**atoptics.co.uk/tiltsun.htm**) and WinJupos (**jupos.org/gh/download.htm**), can determine the correct values for your observations. It's easier to use an equatorial mount, although TiltingSun can also work for altaz setups.

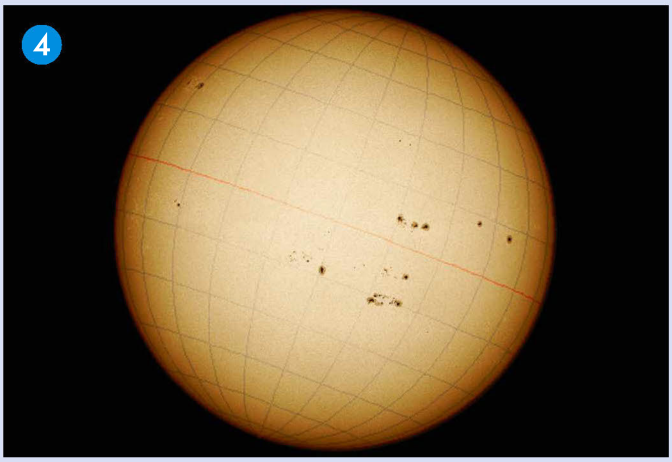
Assuming you have an imaging setup on an equatorial mount, before you start imaging, orient the camera so disc features pass horizontally across the field when slewing in right ascension (see step 1, below). Then work out north, south, east and west (step 2). Using TiltingSun's graphic mode, enter the observation date and time (step 3). The program provides values for B_0, L_0 and P. B_0 is the heliographic latitude of the central point of the Sun's disc and varies by +/– 7.23°. L_0 is equivalent to Earth's Greenwich meridian and is the point on the Sun's disc which marks 0° heliographic longitude. This is a point which is described as having occurred on 1 January 1854 at 12:00 UTC and is calculated thereafter assuming a rotation period of 25.38 days. P is the position angle of the Sun's rotational axis relative to equatorial north.

Copy the grid you get and paste it into a separate layer on top of your full-disc solar image in your graphics editor. Adjust the grid's size to match the disc, then set its blend mode to overlay and opacity to 50 per cent. You can now work out positions from the displayed heliographic latitude and longitude grid lines (step 4).







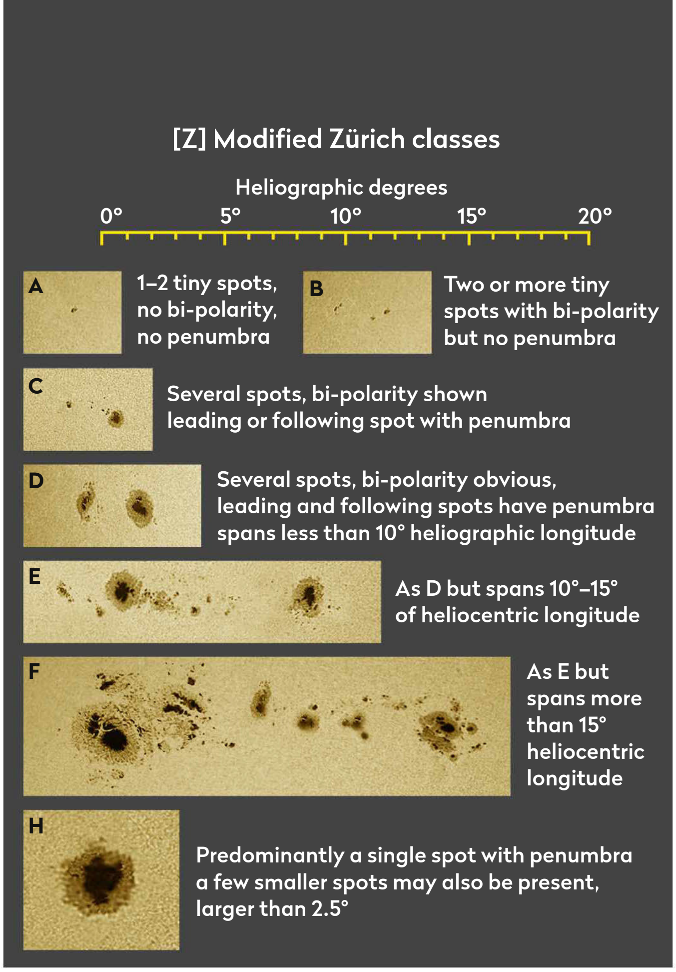


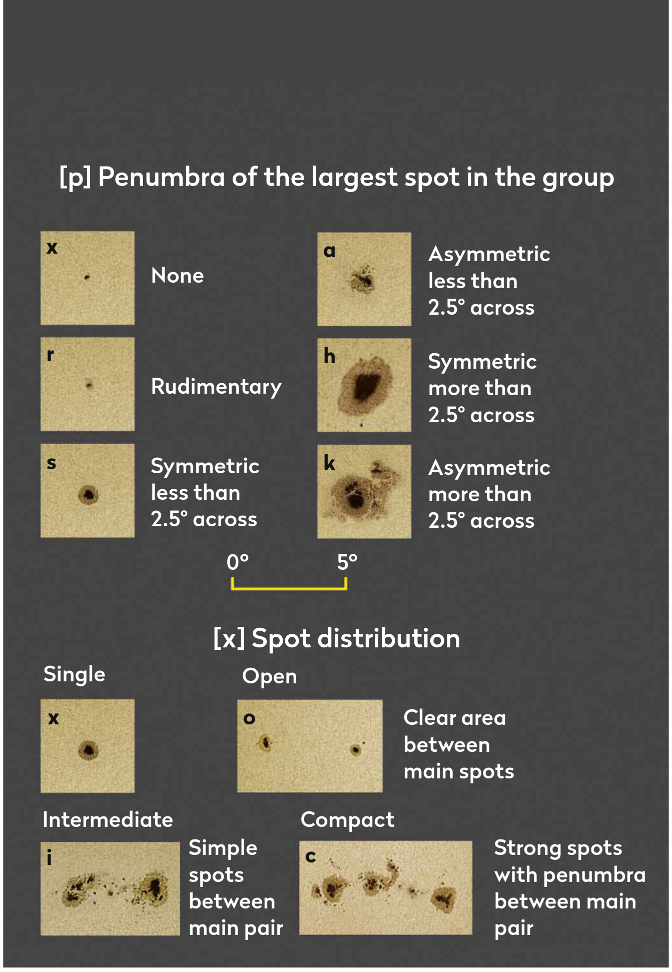
ALL PICTURES: PETE LAWRENCE

▶ of p and x. Taken together, the three letters provide an accurate classification scheme for sunspot groups.

The first few times you give this a go, be aware that it's common to understand what's happening in a diagram only to feel somewhat flummoxed when looking at a real view. Don't worry about this; simply give yourself time to practise. Once you get into the swing of it, doing a McIntosh classification shouldn't take that much longer than performing a simple spot count.

Your classifications can be further refined into a single value known as your daily spot quality number: Q. Like the relative sunspot number, this is also easy to calculate. You only need consider the first classification value: the modified Zürich class. Assign the values A=1, B=2, C=3, D=4, E=5, F=6 and H=3. Calculate the total value for all of the groups you've recorded on one day and this will be that day's value of Q. For example, if you record four groups classified as C, D, E and H, your Q value would be 3+4+5+3=15.





▲ Above left: to take your observations further, you can categorise your sunspots using the modified Zürich classes [Z]

Above right: refine [Z] further with a McIntosh classification of penumbra type [p] and spot distribution [x]

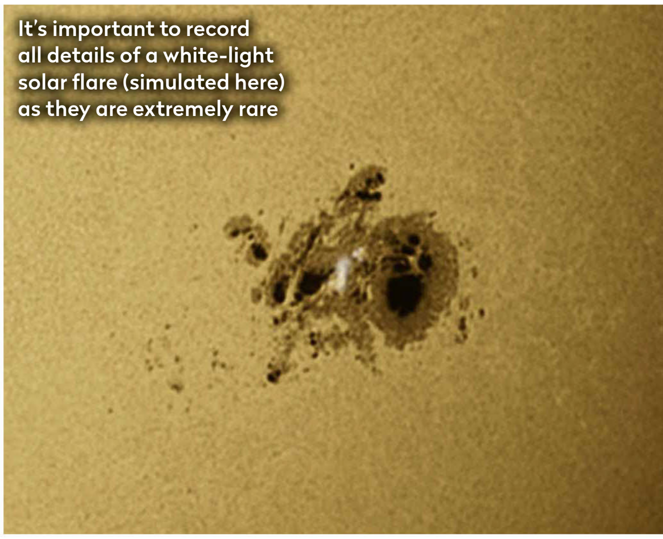
So far, we've described how to observe and record daily values for individual sunspots and sunspot groups. However, other white-light phenomena can be monitored too. The most common features apart from spots are faculae, which appear as bright, often mottled, patches on the photosphere. Towards the centre of the Sun's disc, the photosphere's brightness naturally increases and makes faculae nigh on invisible. However, near to the Sun's edge, limb darkening reduces the photosphere's brightness enough for faculae to clearly stand out.

Faculae represent regions where magnetic forces allow us to peer deeper into the Sun and these deeper, hotter regions appear brighter. Interestingly, at solar maximum the Sun's irradiance – the power per unit area received from the Sun – isn't lowered by the larger numbers of dark and cooler spots, but actually increases by around 0.1 per cent due to the existence of faculae.

Faculae and flares

A simple observation of faculae requires nothing more than performing a count of separate regions. A special case of particular interest are polar faculae, which occur between heliographic latitude 60–90˚. These are smaller than regular main zone faculae and dimmer, typically 3–10 per cent brighter than the photosphere, compared to 9–16 per cent for main zone faculae. They are short-lived too, persisting on timescales of minutes to several hours, although on rare occasions polar faculae may exist for several days. Polar faculae typically show peak activity around solar minimum.

Another, very rare event is the white-light flare, a phenomenon representing a massive outburst of energy. Commonly seen through hydrogen-alpha filters, flares have to be extremely energetic to appear in white light and if one is suspected it's important to record as much detail about it as possible while visible. A typical white-light flare will appear as an intensely bright area within a sunspot group.



It's important to record all details of a white-light solar flare (simulated here) as they are extremely rare

Using a telescope and a white-light filter, it's easy to record meaningful data about current and future solar activity. Over the long term, this information provides valuable insight into the Sun's cycles, recording the ebb and flow of sunspots, sunspot groups and faculae over time. As the Sun approaches its next solar maximum, currently estimated to occur in July 2025 (plus or minus eight months), now is the perfect time to start your record-keeping.

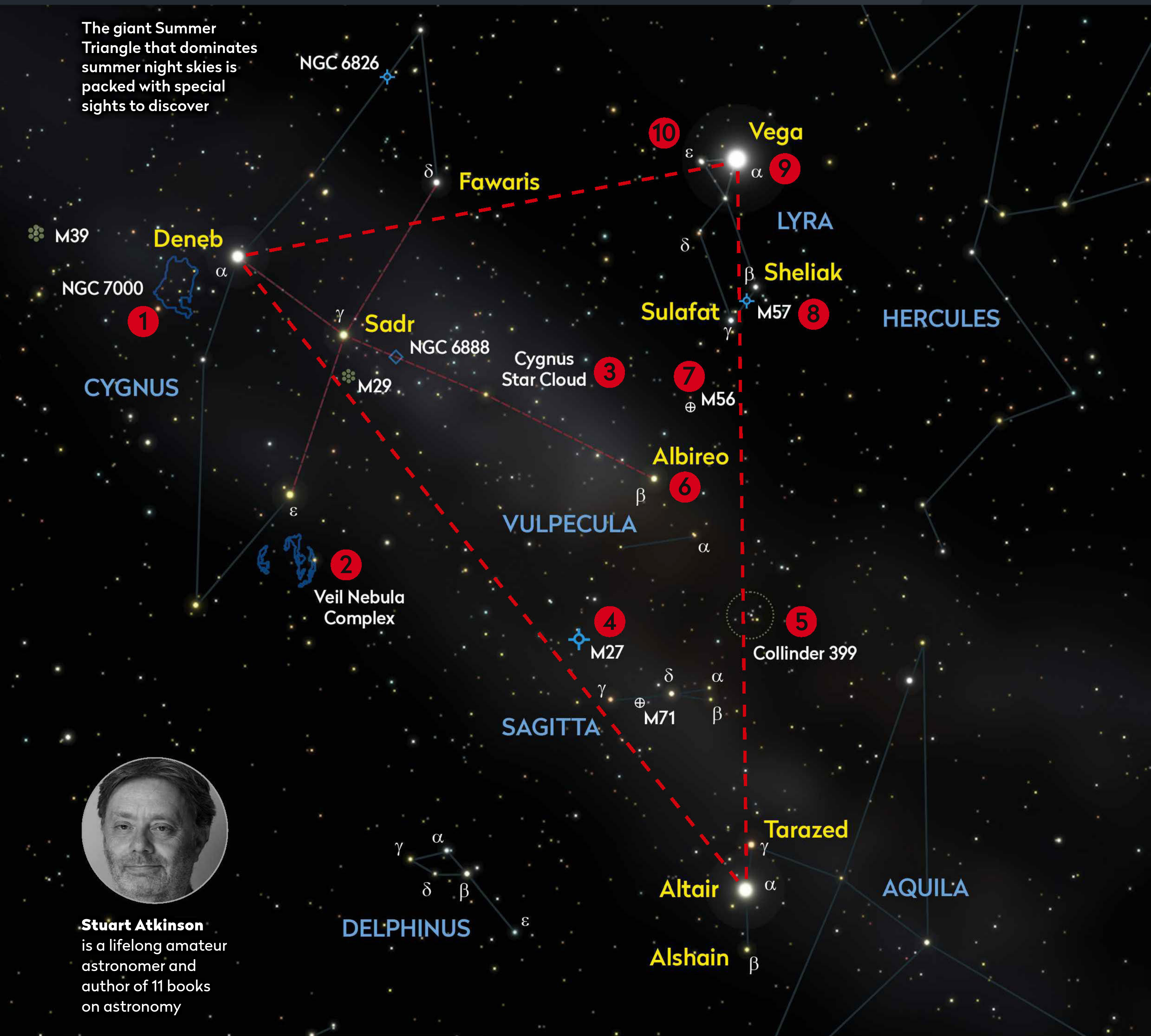
▶ Find out how to photograph the Sun in white light and using other filters on page 76

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* on BBC Four

Summer Triangle treats

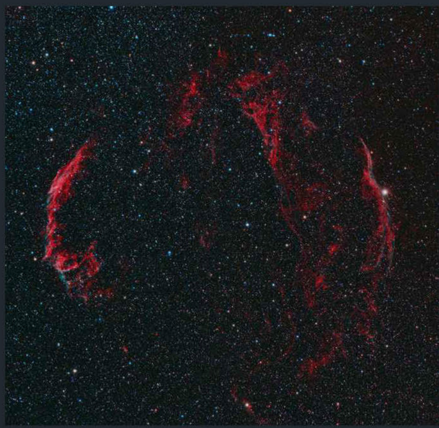
Stuart Atkinson uncovers the delights waiting to be viewed in one of summer's most familiar star patterns

The Summer Triangle is one of the best-known asterisms in the night sky. Made out of three bright stars – Deneb, Vega and Altair – it's often among the first star patterns that newcomers to astronomy identify, because it's so obvious to the naked eye. More experienced observers love it because a host of celestial summer sights can be found inside and around it, all of which are visible to the naked eye or through binoculars. Wait until the darkest time of the balmy summer nights and look out for these 10 of the best…



The giant Summer Triangle that dominates summer night skies is packed with special sights to discover

Stuart Atkinson is a lifelong amateur astronomer and author of 11 books on astronomy



1. North America Nebula
To the left of Deneb you'll see, out of the corner of your dark-adapted eye, a large smudge around four times as wide as the Moon. Through a small telescope this huge, faraway cloud of gas and dust, NGC 7000, looks like North America.

2. Veil Nebula
About 10,000 years ago, a huge star blew up in a supernova. All we can see of it now are faint arcs of misty light. Visible faintly through binoculars, it is best seen through a telescope, especially its brightest and densest sections.

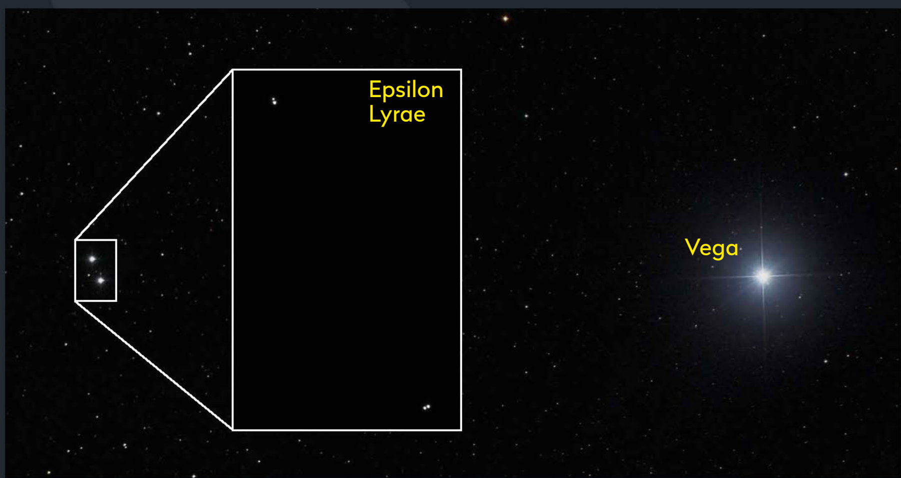
3. Cygnus Star Cloud
Running down the right side of the Northern Cross, this star cloud looks like it has been airbrushed on the sky by some astronomical artist. Switch to binoculars or small telescopes and it resolves into countless faint stars.

4. M27
Seventh-magnitude M27, the Dumbbell Nebula, is often hailed as the most beautiful planetary nebula in the sky. It is visible in binoculars, but telescopes will reveal hints of its pale green colour.

5. The Coathanger
This small asterism is a spray of several dozen stars, the 10 brightest of which really do form the shape of a celestial coathanger! Almost all are blue, but one marmalade-orange star really stands out.

6. Albireo
Albireo is one of the most popular double stars because of the contrasting colours of the pair – one a lustrous gold hue, the other a rich, azure blue – which are very obvious through even a small scope.

7. M56
Although overshadowed by larger, brighter M13 nearby, this is still an attractive misty globular cluster in binoculars and small scopes. It lies 31,000 lightyears away and is a ball of thousands of suns.



8. M57
Look at this planetary nebula through binoculars or small telescopes and you'll see why it's known as the Ring Nebula: it is a small, oval, light grey smoke ring. This shell of gas and dust blown out by a dying star is around 2,300 lightyears away, and glows at magnitude +8.8.

9. Vega
With a magnitude of +0.03, Vega is the fifth-brightest star in the sky. A blue-white star 25 lightyears away, it is also known as the Harp Star because of its position within the Lyre. In 210,000 years it will become the brightest star in the sky, shining at magnitude –0.8.

10. Epsilon Lyrae
This fifth-magnitude double star can be found very close to Vega, and can be split easily with binoculars and even with the naked eye if your eyesight is good. It is often referred to as the Double Double, because each of its members is also a double star.

CHART BY PETE LAWRENCE, WWW.CCDGUIDE.COM X 7, SATORU S/ ISTOCK/GETTY IMAGES, M-GUCCI/ISTOCK/GETTY IMAGES

16-PAGE CENTRE PULLOUT

BBC Sky at Night MAGAZINE

The Sky Guide

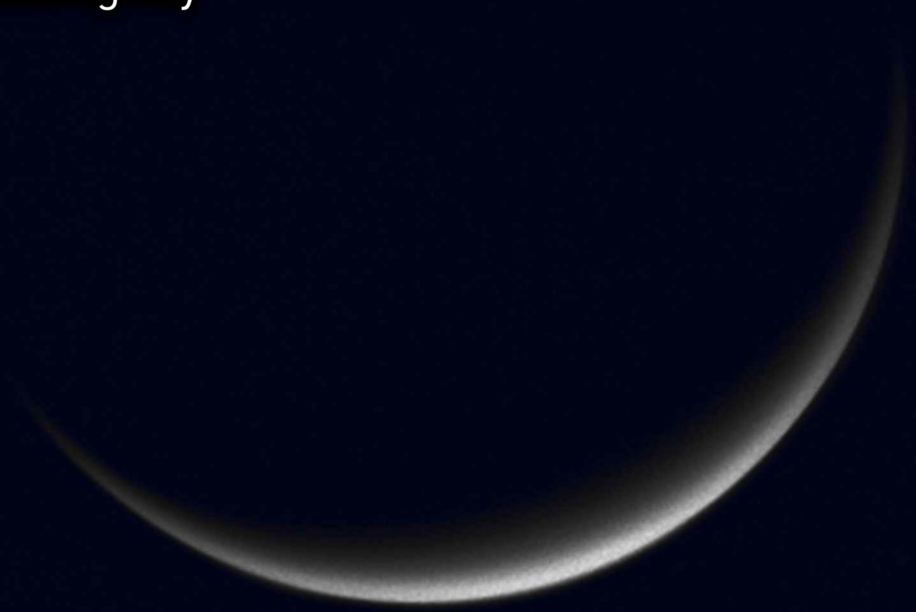
JULY 2023

CATCH THE CRESCENT

Track the waning crescent Venus as it gets more beautiful in the eyepiece with each passing day

PLUTO AT OPPOSITION

Can you image the distant minor planet?



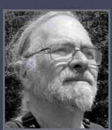
PETE LAWRENCE

SUMMER STUNNERS

Take our Deep-Sky Tour of beautiful summer clusters

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four



Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month…

- ✦ A chance to spot NLC displays
- ✦ Perseid activity begins
- ✦ Jewelled Handle clair-obscur effect visible on the Moon

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

JULY HIGHLIGHTS

Your guide to the night sky this month

All month

June and July are the best months for spotting elusive noctilucent clouds (read more on page 47).

Saturday 1

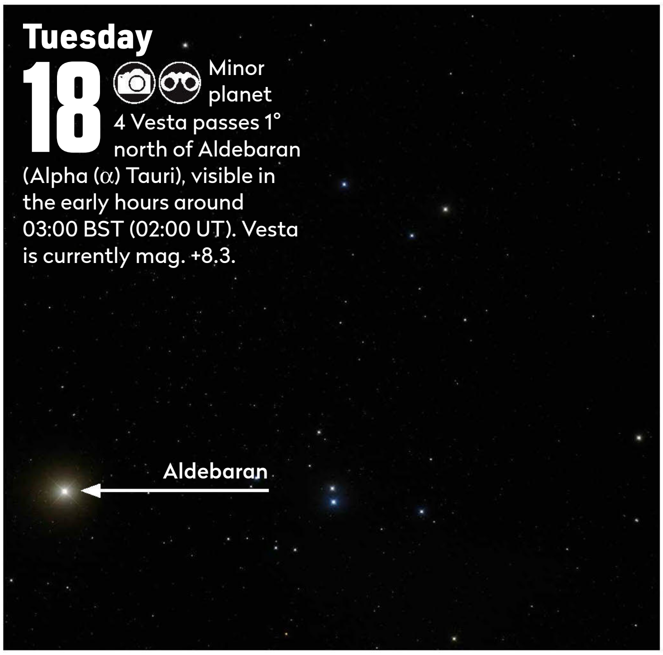
Mag. –4.3 Venus appears low in the west-northwest around 23:00 BST (22:00 UT). Binoculars show the orange-hued dot of mag. +1.7 Mars and mag. +1.3 Regulus nearby.

Monday 10

Locate Venus low in the west-northwest as darkness falls, with mag. +1.7 Mars 4.8° to the west of it. This evening, Mars is 0.7° from Regulus (Alpha (α) Leonis).

Wednesday 12

This morning's 29%-lit Moon rises just after 01:00 BST (00:00 UT), accompanied by mag. –2.1 Jupiter, 2.9° to the southwest.



Tuesday 18

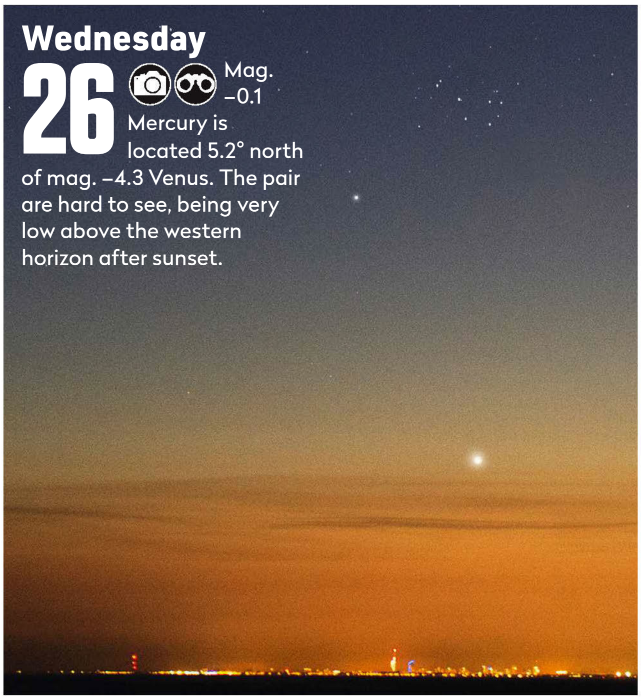
Minor planet 4 Vesta passes 1° north of Aldebaran (Alpha (α) Tauri), visible in the early hours around 03:00 BST (02:00 UT). Vesta is currently mag. +8.3.

Wednesday 19

Just after sunset it may be possible to spot mag. –4.3 Venus, mag. –0.3 Mercury and a slender 4%-lit waxing crescent Moon, very low above the west-northwest horizon.

Saturday 22

Dwarf planet Pluto reaches opposition. Currently shining at mag. +14.4, Pluto is in Sagittarius, around 1.5° south of mag. +8.6 globular cluster M75.



Wednesday 26

Mag. –0.1 Mercury is located 5.2° north of mag. –4.3 Venus. The pair are hard to see, being very low above the western horizon after sunset.

Family stargazing

On the evening of 27 July, a look at the Moon through binoculars or a telescope will show an arc of light extending into the dark part of the Moon's disc. The arc is caused by the light of the lunar dawn hitting the lofty peaks of the Jura Mountain range, which borders a lava bay called Sinus Iridum, the Bay of Rainbows. This is what's known as a clair-obscur effect – a trick of the light. If you have clear skies on 27 July, why not suggest using a piece of paper and a pencil to make a drawing of this lovely sight? **www.bbc.co.uk/cbeebies/shows/stargazing**

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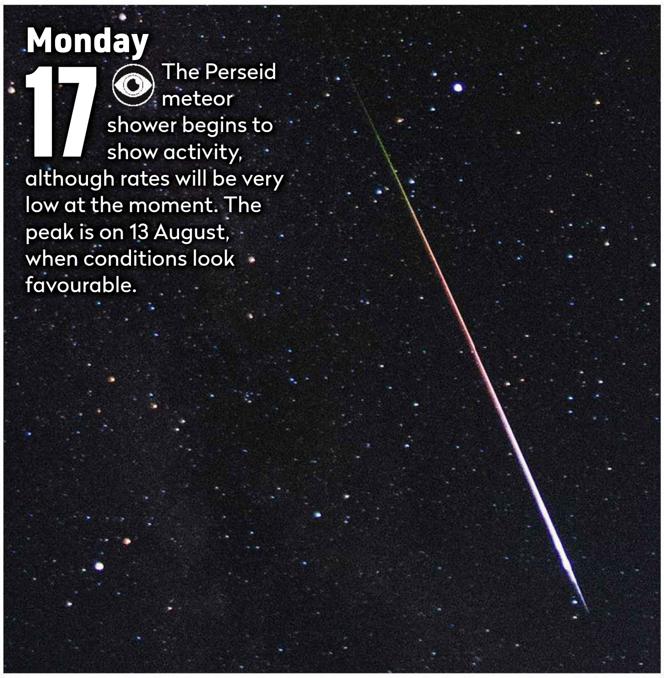
Thursday
6 The Moon's northern polar region is currently tilted towards us, thanks to lunar libration.

Friday
7 Mag. +0.6 Saturn sits 4° north of the 81%-lit waning gibbous Moon in the early hours.

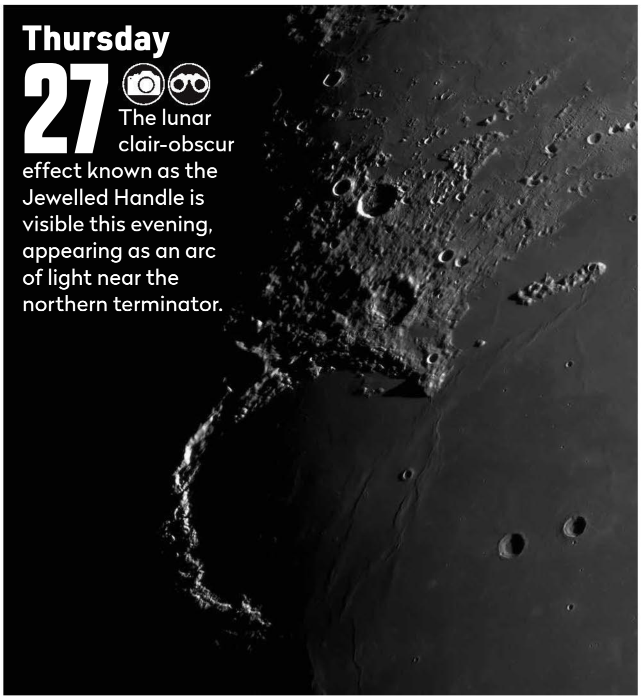
Sunday
9 See Venus over towards the west-northwest after sunset. Today, the planet approaches maximum brightness at mag. –4.4. Its position isn't optimal at present.

Thursday
13 The 20%-lit waning crescent Moon sits 4.2° southwest of the Pleiades open cluster. Catch them above the northeast horizon around 02:00 BST (01:00 UT).



Monday
17 The Perseid meteor shower begins to show activity, although rates will be very low at the moment. The peak is on 13 August, when conditions look favourable.

Monday
24 Ninth-magnitude comet C/2020 V2 ZTF has been close to Uranus and Jupiter over past weeks, but unfavourably positioned. This is now changing. Check page 47 for details.



Thursday
27 The lunar clair-obscur effect known as the Jewelled Handle is visible this evening, appearing as an arc of light near the northern terminator.

Friday
28 Find the Moon around 18:30 BST (17:30 UT), low in the southeast. Using binoculars or a telescope, can you spot the mag. +1.0 star Antares just south of its southern limb?

Saturday
29 The end of July sees the peak of the Southern Delta Aquariid meteor shower, although a bright Moon will interfere this year.

NEED TO KNOW
The terms and symbols used in The Sky Guide

Universal Time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

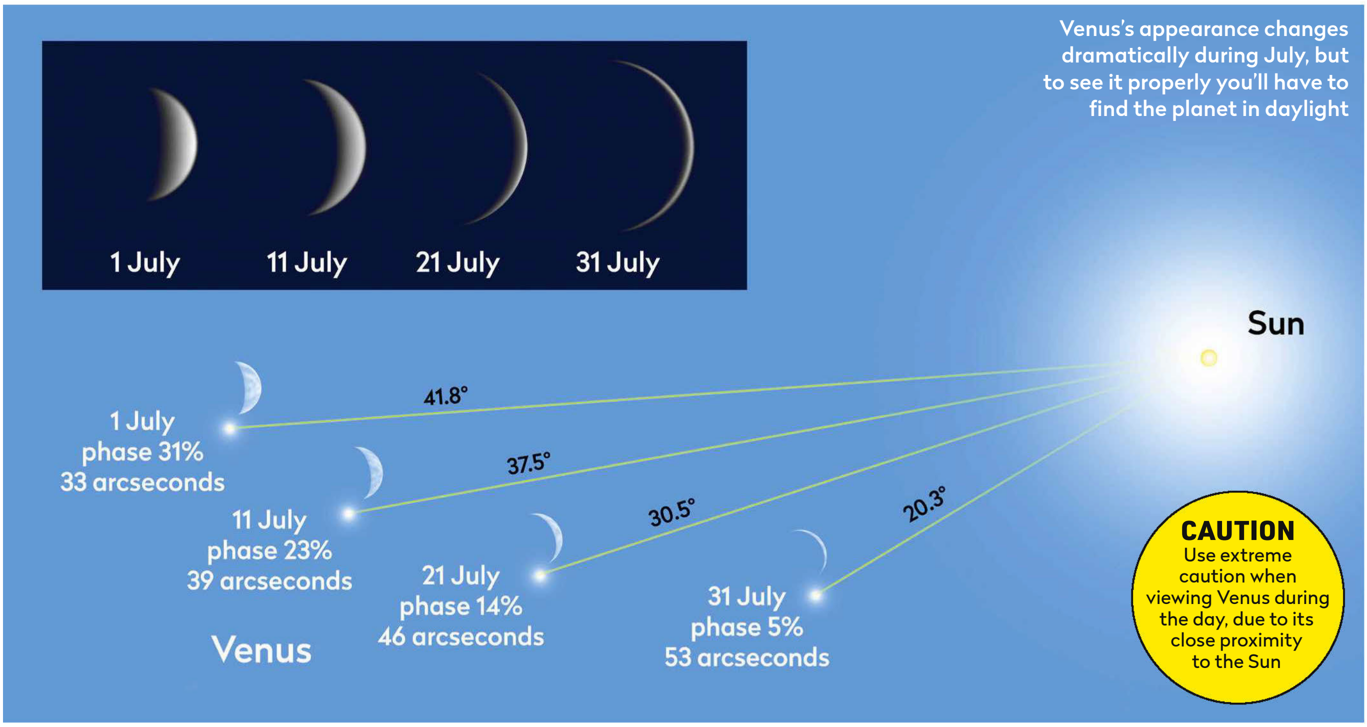
Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY
If you're new to astronomy, you'll find two essential reads on our website. Visit **bit.ly/10_easylessons** for our 10-step guide to getting started and **bit.ly/buy_scope** for advice on choosing a scope

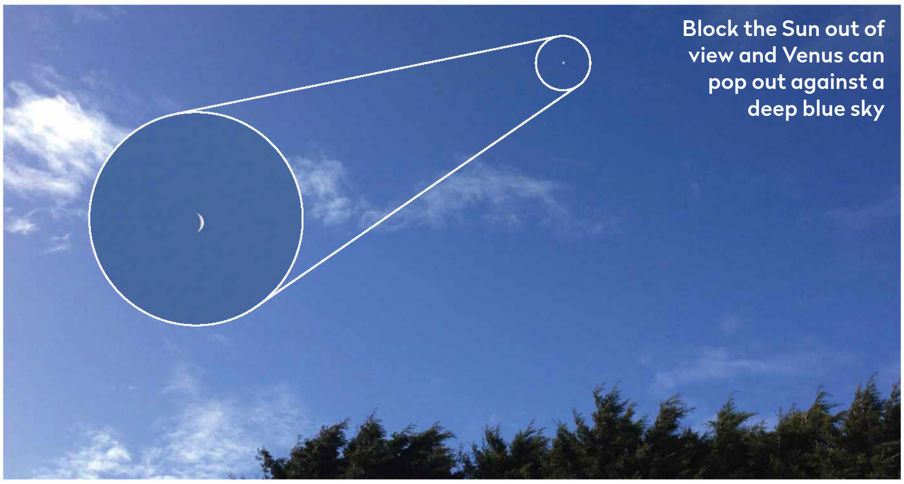
THE BIG THREE The top sights to observe or image this month



DON'T MISS

Follow the crescent

BEST TIME TO SEE: All month


Block the Sun out of view and Venus can pop out against a deep blue sky

Venus has been dominant in the UK's evening sky for months, but during July its position after sunset rapidly deteriorates. Although a shame for naked-eye views, it's through the telescope that things are really starting to get interesting – the caveat is, you'll need to find it during the day.

In a dark sky, Venus's brightness works against it through a telescope. Its intense glare is jostled by the unsteady seeing you get at low altitude after sunset (or before sunrise when it's in the morning sky). During the day, it gets higher and can be seen under steadier conditions. A blue sky also reduces contrast. Together these factors make observing Venus in daytime skies a better prospect all-round.

Locating Venus by day can be done by eye but does take a bit of practice. It's essential that you are aware of solar safety at all times to protect your eyesight and equipment. Standing in the shadow of a building or other structure is a good way to block any unwanted view of the Sun.

Using a Go-To-enabled mount pre-aligned the night before will allow you to go to Venus with computer assistance. Alternatively, setting circles can be very helpful for locating Venus during the day.

On 1 July, Venus sets nearly two hours after sunset. This offset decreases all month, and on 31 July Venus sets at the same time as the Sun. On 1 July, the planet appears separated from the Sun by 41.8°. Through the eyepiece it appears as a 31%-lit crescent 33 arcseconds across – a very beautiful sight.

On 10 July, the separation from the Sun is 37.5°, the planet setting 80 minutes after the Sun and appearing 23%-lit and 39 arcseconds across. By 20 July, things will have changed dramatically. Its separation from the Sun drops to 30.5° and it sets 45 minutes after sunset. An 8%-lit crescent Moon sits 7.1° above Venus as seen from the UK. Through an eyepiece, the planet appears 14%-lit and 46 arcminutes across.

After 20 July, daytime viewing is recommended. On 31 July at 14:26 BST (13:26 UT), Venus appears due south at an altitude of 44° (half-way up the sky). Separated from the Sun by 20.3°, through a telescope it will appear as a stunning 5%-lit crescent, 53 arcseconds across.

ALL PICTURES: PETE LAWRENCE

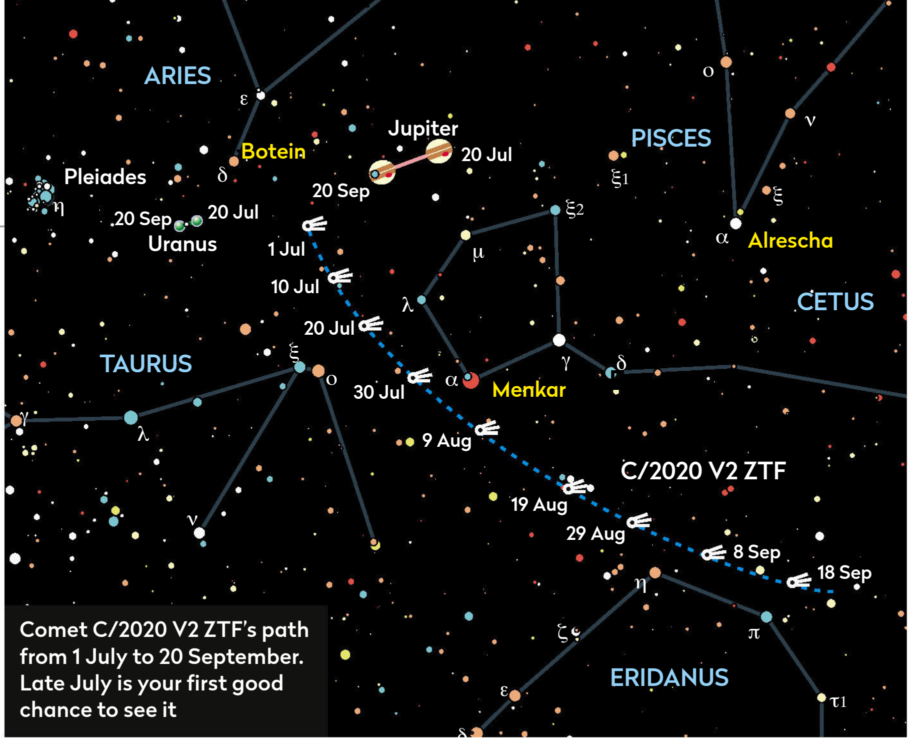
Comet C/2020 V2 ZTF

BEST TIME TO SEE: Last week of July, then mid-August

Comet C/2020 V2 ZTF is currently visible through a telescope or large binoculars in pre-dawn skies. At the start of July, it is near Uranus, but the bright post-solstice sky may thwart attempts to see it properly. As darkness returns, the comet shyly heads south to end the month east of the distorted pentagonal shape representing the head of Cetus, the Whale. Although it does brighten, the bad news is that it's not by much, starting the month at mag. +10.0 and ending it at +9.8. The balance between position and sky brightness will be a tricky one and it's probably not going to be a viable target until the last week of July. Even then, it will remain challenging to view from more northerly locations.

As the end of the month approaches, the darker sky and the more elevated position of the comet before morning twilight engulfs it should make it a potential target in the early hours. The Moon is in its first quarter phase on 25 July and although it tries to encroach on the comet at the very end of July, it should be possible to grab a short window of relative darkness after moonset.

The Moon will then interfere badly at the start of August (something we can happily put up with because it means it will be out of the way in mid-August, when the Perseids reach their peak). As the Moon moves out of the way again in August, the comet will be in a better observing position, attaining a higher altitude in darker skies around mid- to late August. Throughout much of August, the comet is predicted to reach a magnitude of around +9.1, continuing its southern motion and ending the month near the mag. +3.9 star Eta (η) Eridani.



Comet C/2020 V2 ZTF's path from 1 July to 20 September. Late July is your first good chance to see it

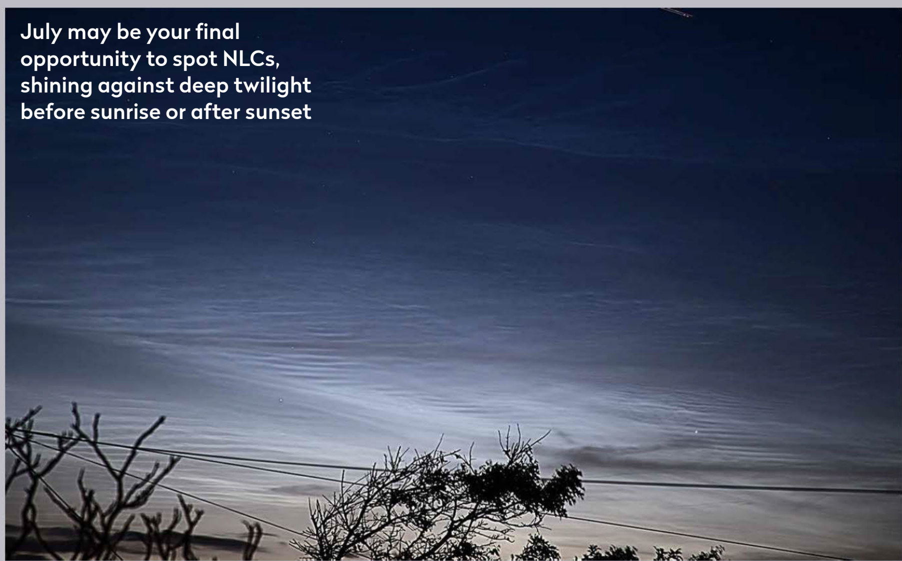
NLC season continues

BEST TIME TO SEE: All month at twilight, at the times stated

Noctilucent cloud (NLC) season continues into July, typically petering out in early August, although displays may still be possible through to mid-August. If present, these high-altitude ice-sheet clouds typically appear low above the northwest horizon 90–120 minutes after sunset or a similar time low above the northeast horizon before sunrise. Extensive displays can buck this trend and it's worth bearing in mind that NLCs don't always play by the 'rules'!

There are many different forms of NLC, described by a variety of different classifications. Brightness varies too, from barely visible through to so bright that they are impossible to miss. They get their name 'noctilucent', meaning 'night-shining', from the fact that although the Sun is below the horizon for us on the ground, at their great altitude of 82km it is still visible. As a result, the reflected sunlight makes them appear to shine at night.

Interestingly, from the perspective of tropospheric clouds (regular clouds), the Sun has also set. If these are present on a night when NLCs are shining, tropospheric clouds look dark, silhouetted against their loftier counterparts. Another interesting effect occurs if the Moon appears behind NLCs. Unlike normal high-altitude hazy clouds which scatter moonlight, NLCs act like a thin film and don't appear to interact with moonlight at all.

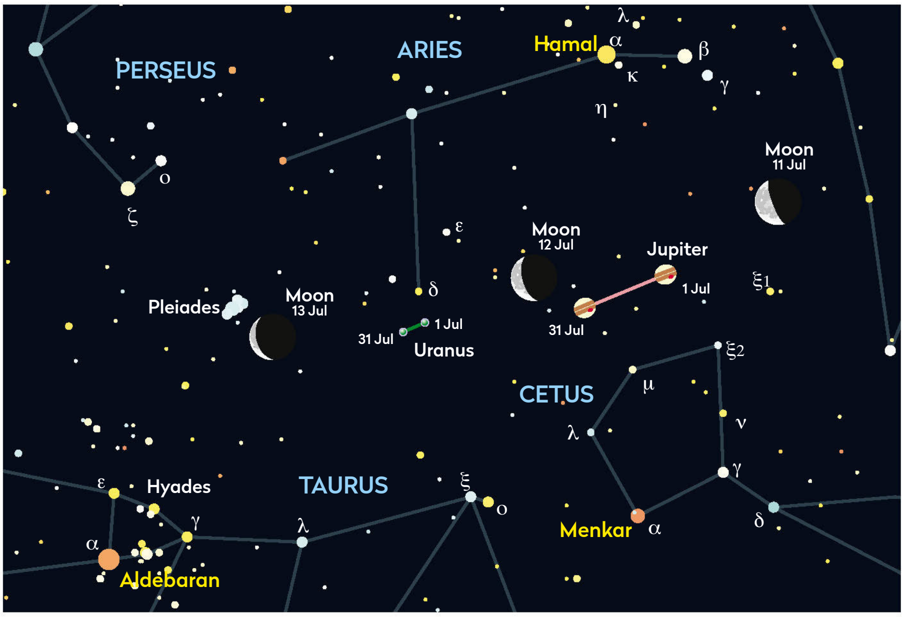


July may be your final opportunity to spot NLCs, shining against deep twilight before sunrise or after sunset

PICK OF THE MONTH

Jupiter

Best time to see: 31 July
Altitude: 30°
Location: Aries
Direction: East-southeast
Features: Complex atmosphere, Galilean moons
Recommended equipment: 75mm or larger



▲ Jupiter is now north of the 'head' of Cetus, its position improving as it gains altitude

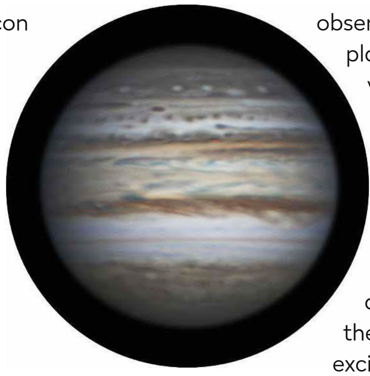
Jupiter manages a decent altitude under dawn twilight by the end of July. Currently a morning planet, mag. –2.1 Jupiter appears 2.9° from a 29%-lit waning crescent Moon on the morning of 12 July, rising above the east-northeast horizon around 01:20 BST (00:20 UT).

The planet has moved east from Pisces where it was last year and now sits in southern Aries. This is excellent news for the months ahead because as we approach opposition on 2 November 2023, Jupiter will be high in UK skies and visible in dark skies that last for a significant time. Although the skies certainly can't be described that way at present, it's a price worth paying for the spectacle to come.

During July, Jupiter's position slowly improves. On 1 July it rises just before 02:00 BST (01:00 UT) above the east-northeast horizon, a beacon shining at mag. –2.1. By the time the sky starts to brighten before sunrise, Jupiter is around 20° altitude above the east horizon.

By the end of July, Jupiter rises at midnight BST (23:00 UT) and reaches an altitude of around 40° above the southeast horizon under brightening twilight. Consequently, this is an excellent time to start observing and recording the planet. By 31 July, Jupiter will have brightened very slightly to shine at mag. –2.2.

From the UK we can look forward to Jupiter reaching an altitude of around 50° under dark sky conditions in the weeks that follow – an exciting prospect, as it will raise the planet above the turbulent atmosphere that can otherwise blur fine detail in its atmosphere.

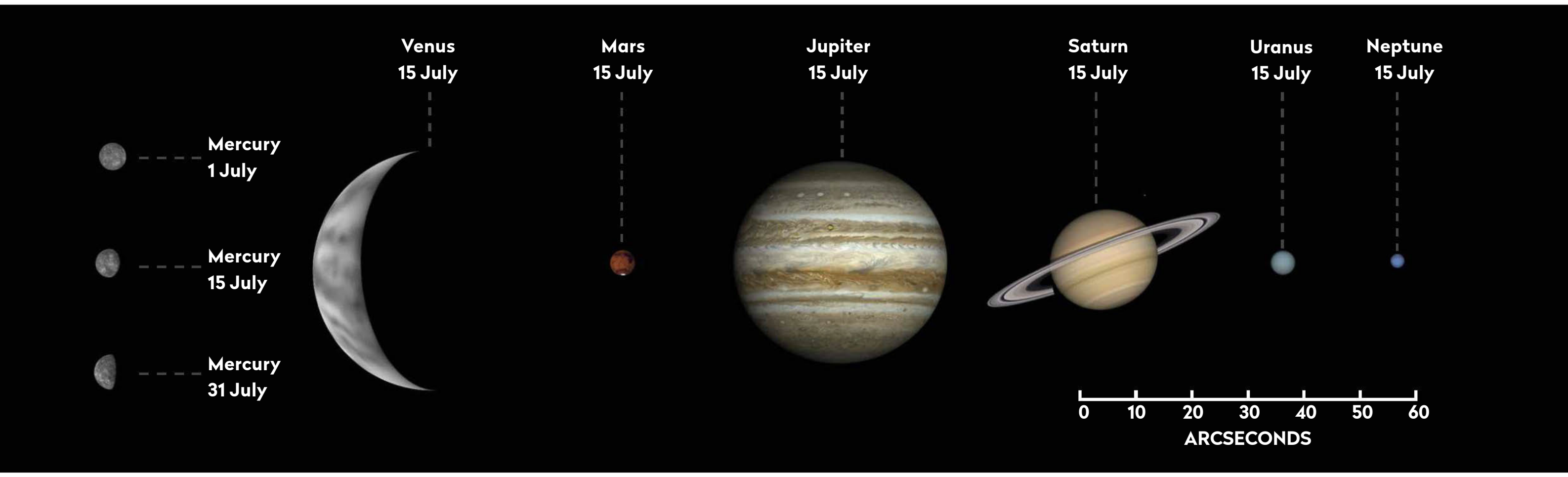


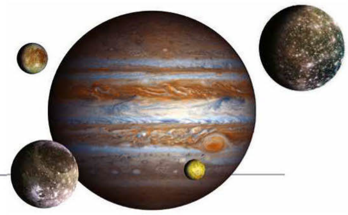
▲ Jupiter is a fine planet to observe, showing an abundance of detail in its complex atmosphere

PETE LAWRENCE X 2

The planets in July

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Mercury

Best time to see: 15 June, 30 minutes after sunset
Altitude: 2° (very low)
Location: Cancer
Direction: West-northwest
Mercury reaches superior conjunction on 1 July, thereafter slowly emerging into the evening sky. It's best mid-month. On 10 July, mag. –1.0 Mercury sets 50 minutes after sunset. By 25 July, Mercury dims to mag. –0.1, setting one hour after sunset. At July's end, Mercury is near Venus. On 28 July, mag. +0.1 Mercury is 14 arcminutes from the mag. +1.3 star Regulus (Alpha (α) Leonis).

Venus

Best time to see: 1 July, 30 minutes after sunset
Altitude: 5° (low)
Location: Leo
Direction: West
Venus is currently approaching Earth, an evening planet with a poor position after sunset. Mag. –4.3 Venus sets less than 2 hours after sunset on 1 July, but by 31 July the offset is just a minute or two! On 19 July, mag. –4.3 Venus is joined by mag. –0.3 Mercury, 13.2° to the right (northwest) and a slender 3%-lit waxing crescent Moon 4.3° above left (east-northeast) of Mercury. Venus is a 33-arcsecond, 31%-lit waning crescent on 1 July. By 31 July its phase reduces to 5% and it appears 53 arcseconds across, its beautifully thin crescent best observed in daytime.

Mars

Best time to see: 1 July, 1 hour after sunset
Altitude: 9° (low)
Location: Leo
Direction: West
Mars hangs on in the evening twilight but is hard to see due to low altitude. On 1 July, shining at mag. +1.7, it's near mag. –4.3 Venus. On the evening of 9 July, Mars is 0.8° from mag. +1.3 Regulus, tricky to see under bright twilight. From the UK, an 8%-lit waxing crescent Moon sits right of Mars on 20 July.

Saturn

Best time to see: 31 July
Altitude: 26°
Location: Aquarius
Direction: South
Saturn is improving dramatically. Visible in the morning on 1 July, mag. +0.6 Saturn manages an altitude of 17° above the southeast horizon under dark twilight. By the end of the month, Saturn reaches its highest altitude of 25°, due south under darkness. A bright 81%-lit waning gibbous Moon sits 3.8° south of Saturn on 7 July, best around 03:00 BST (02:00 UT).

Uranus

Best time to see: 31 July, 02:30 BST (01:30 UT)
Altitude: 19°
Location: Aries
Direction: East
Too close to the Sun at the start of July. By the end of July Uranus reaches 18° altitude under darkness, shining at mag. +5.8, 9.2° east-northeast of mag. –2.2 Jupiter and 8.7° southwest of the Pleiades.

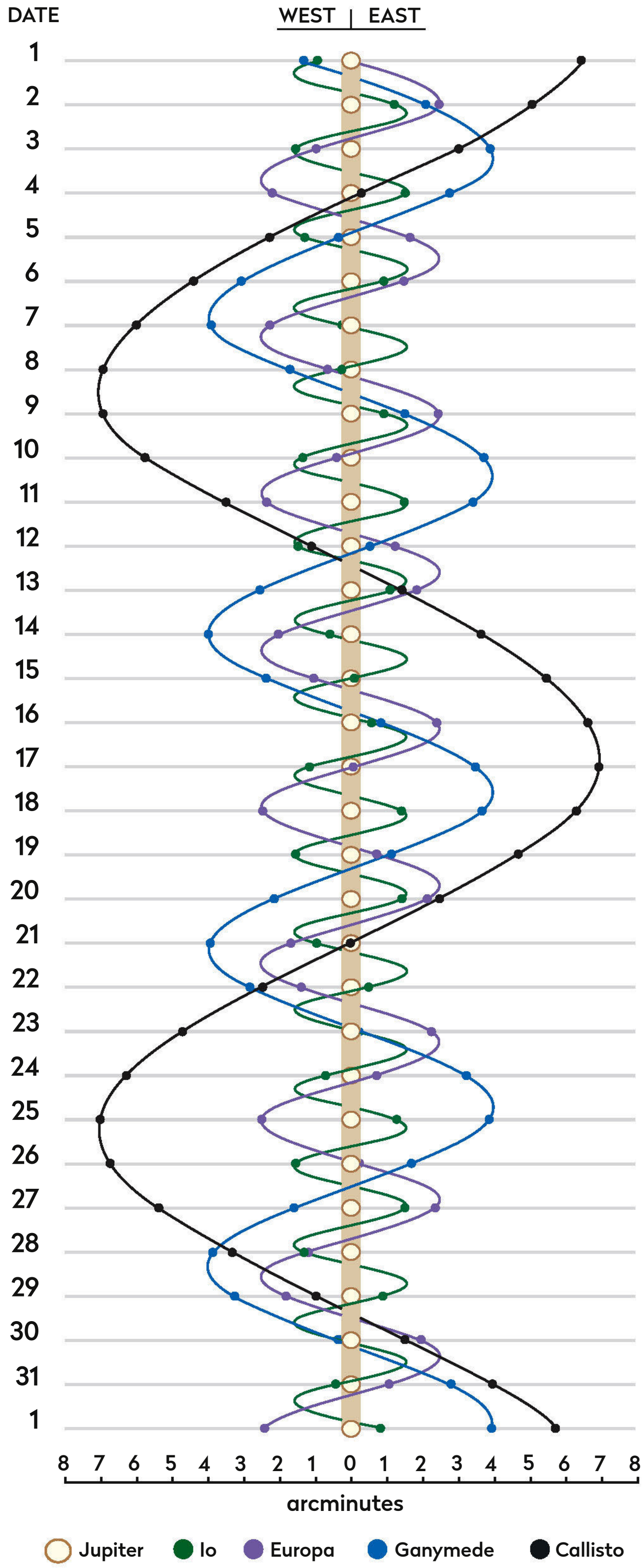
Neptune

Best time to see: 31 July, 02:30 BST (01:30 UT)
Altitude: 29°
Location: Pisces
Direction: Southeast
Neptune is a morning planet in Pisces, southeast of the Circlet asterism. It's best at the end of the month when it manages 29° above the southeast horizon under darkness.

MORE ONLINE
Print out observing forms for recording planetary events

JUPITER'S MOONS: JULY

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically over the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT).



THE NIGHT SKY – JULY

Explore the celestial sphere with our Northern Hemisphere all-sky chart

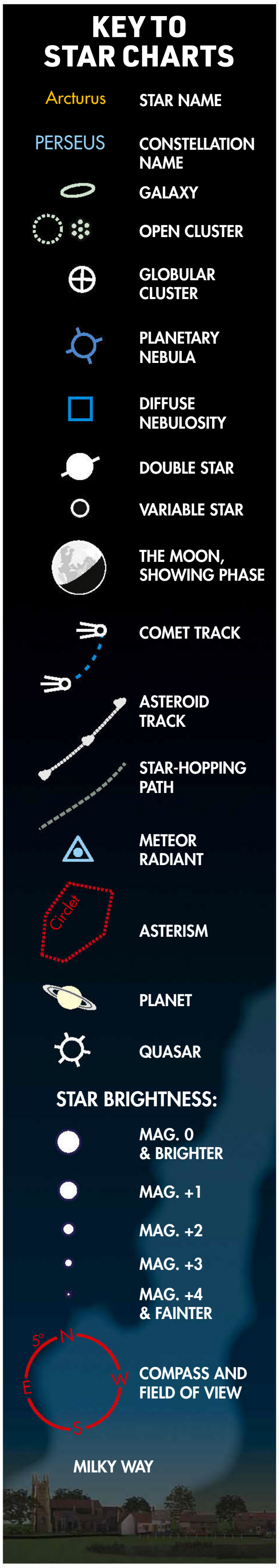


CHART: PETE LAWRENCE

When to use this chart

1 July at 01:00 BST
15 July at 00:00 BST
31 July at 23:00 BST

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in July*

Date	Sunrise	Sunset
1 Jul 2023	04:46 BST	21:42 BST
11 Jul 2023	04:55 BST	21:35 BST
21 Jul 2023	05:08 BST	21:24 BST
31 Jul 2023	05:24 BST	21:08 BST

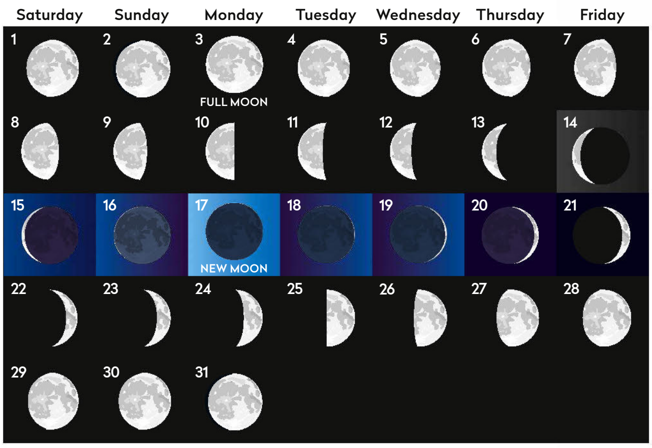
Moonrise in July*

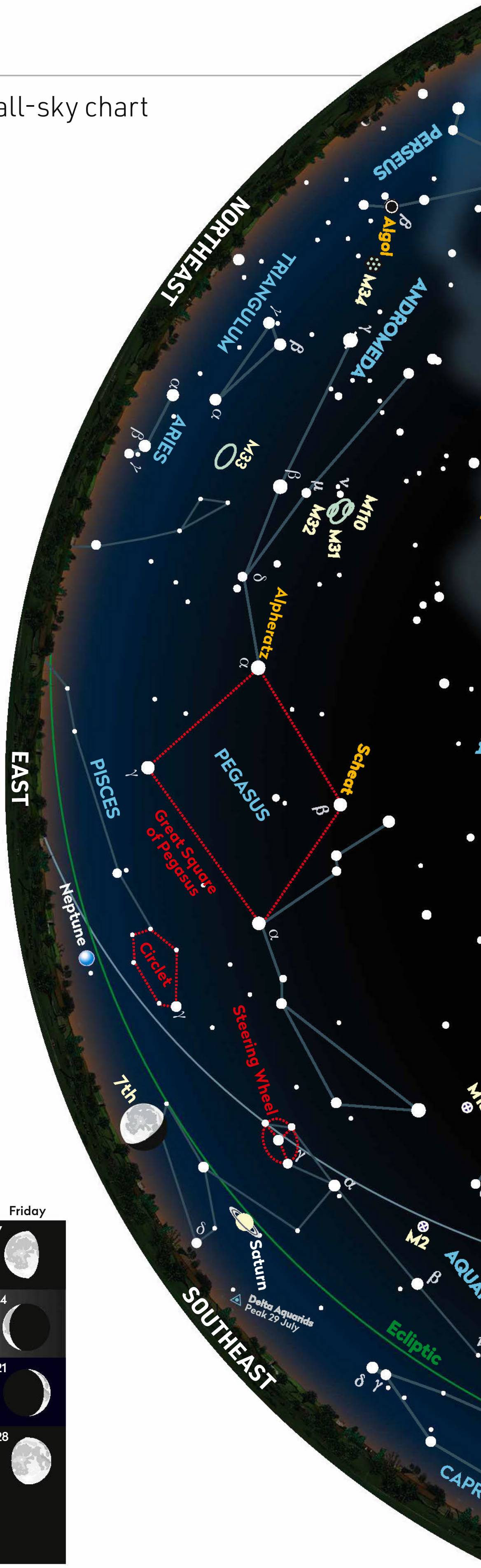
Moonrise times

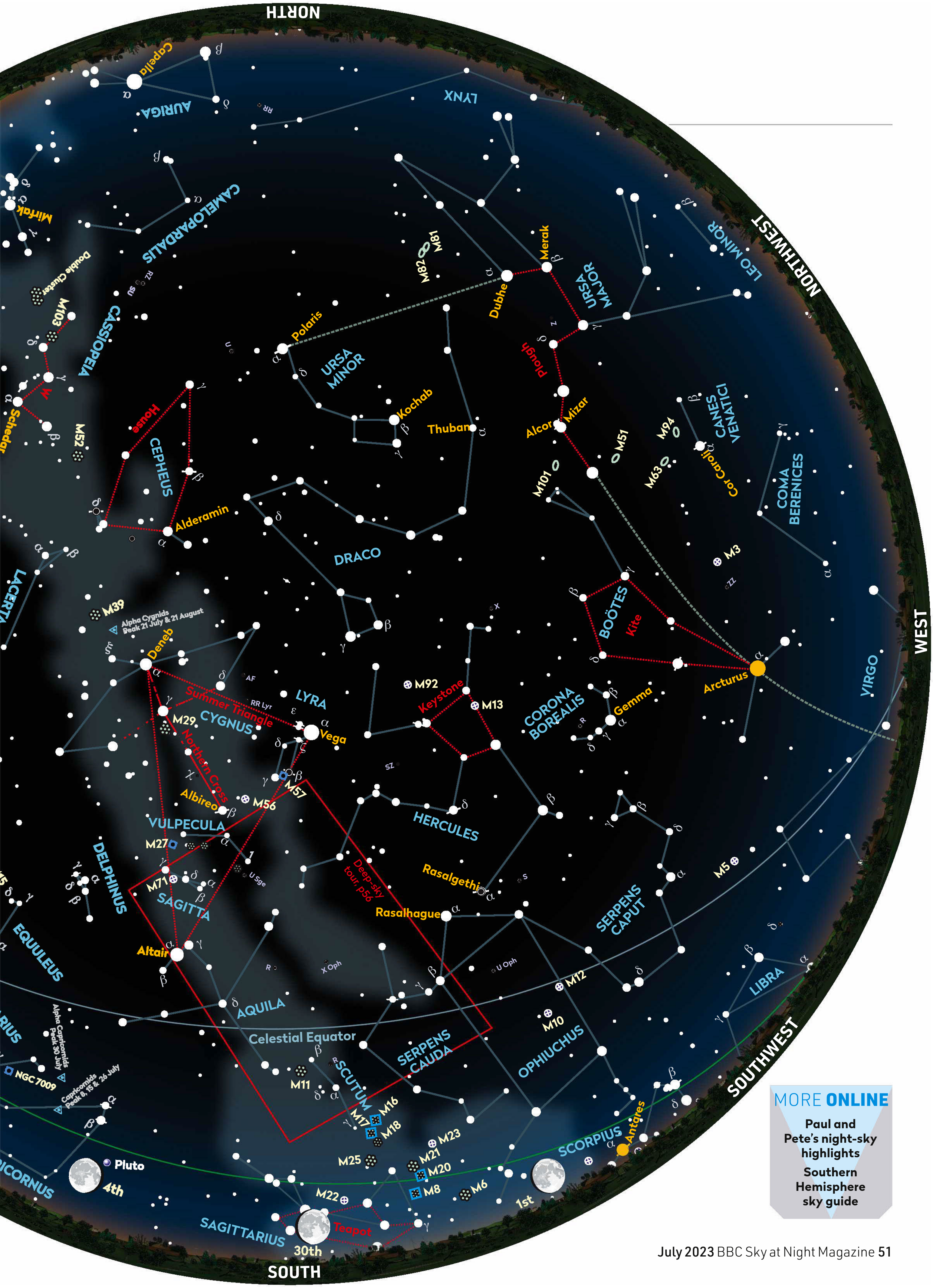
1 Jul 2023, 20:20 BST	17 Jul 2023, 03:53 BST
5 Jul 2023, 23:43 BST	21 Jul 2023, 08:47 BST
9 Jul 2023, 00:23 BST	25 Jul 2023, 13:40 BST
13 Jul 2023, 01:14 BST	29 Jul 2023, 19:15 BST

*Times correct for the centre of the UK

Lunar phases in July







MORE ONLINE

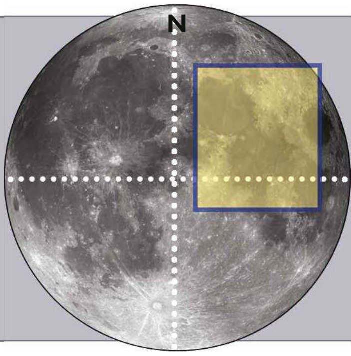
Paul and Pete's night-sky highlights

Southern Hemisphere sky guide

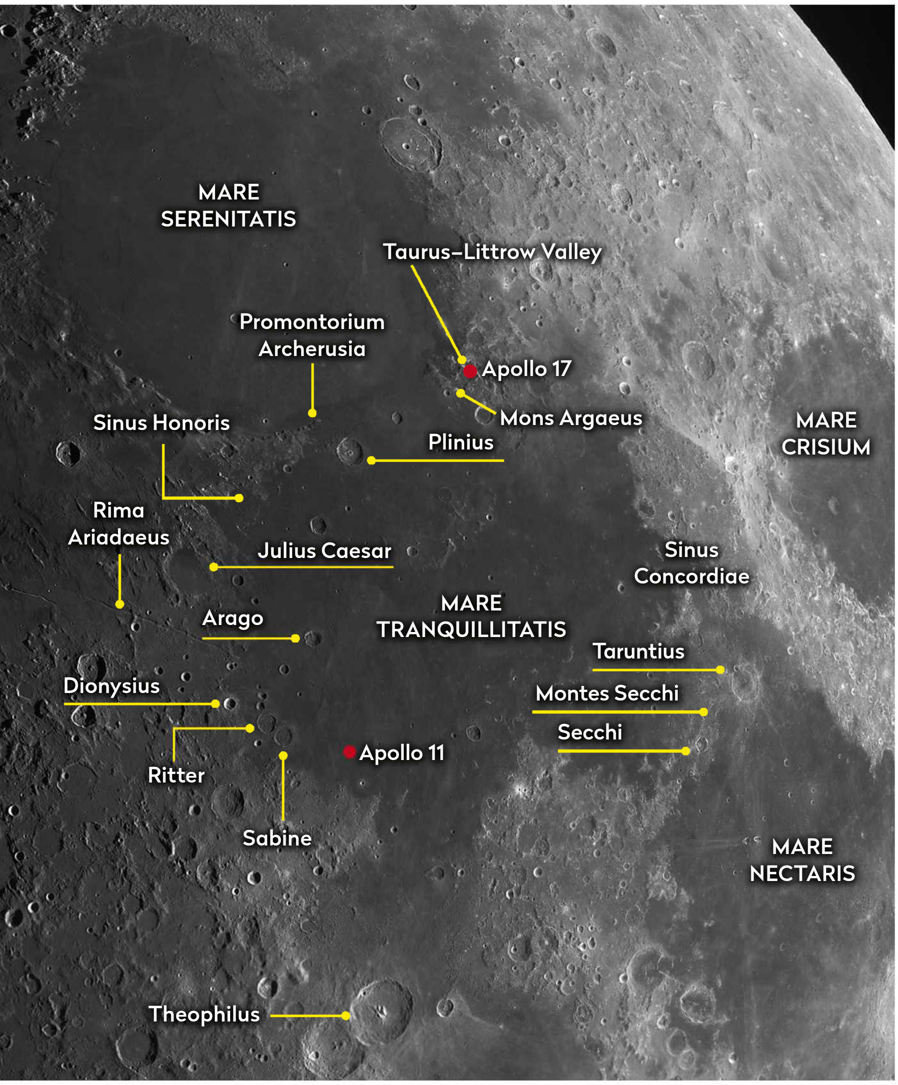
MOONWATCH July's top lunar feature to observe

Mare Tranquillitatis

Type: Lunar Sea
Size: 700x700km
Longitude/latitude: 30.8° E, 8.3° N
Age: Older than 3.9 billion years
Best time to see: Five days after new Moon (21–24 July) or four days after full Moon (7–9 July)
Minimum equipment: Naked eye



Fifty-four years ago, or more precisely on 21 July 1969, Neil Armstrong was the first human to set foot on the Moon, the culmination of the successful Apollo 11 mission. The craft in which he and Buzz Aldrin descended to the lunar surface landed near the southwest shore of **Mare Tranquillitatis**, the Sea of Tranquillity. From Earth, it's one of the defining dark regions of the Moon's familiar face, the central sea of three dark patches in a row, with 650km **Mare Serenitatis** to the northwest and 350km **Mare Nectaris** to the southeast. All three are visible as distinct features to the unaided eye. In angular terms, Serenitatis appears 349 arcseconds, Tranquillitatis 376 arcseconds and Nectaris 188 arcseconds across. The eye can't resolve features smaller than 60 arcseconds. The distinctive and non-joined **Mare Crisium** (620km x 570km, 333 arcseconds) appears immediately east and slightly north of Mare Tranquillitatis.



▼ **The shores of the Sea of Tranquillity are littered with fascinating targets, including both the first and the last Apollo landing sites**

Binoculars will show the region well and reveal the amazing contrast between the old surface of Mare Tranquillitatis and slightly younger Mare Serenitatis. In particular, look at the region between the two seas where the surface contrasts are particularly dramatic. The western border of Tranquillitatis is well-defined, its curving arc starting from the sharp point of **Promontorium Archerusia** in the north, close to the distinctive 43km crater **Plinius**. As you head south, you'll encounter the jagged irregular form of 100km x 70km **Sinus Honoris**, the Bay of Honour, sitting just north of the equally irregular 90km crater **Julius Caesar**. Just south of here is the beautiful **Rima Ariadaeus**, a 7km wide linear rille that runs for 220km across the lunar surface.

Continue past the amazing rays of 18km **Dionysius** towards the twin craters, in appearance anyway, 31km **Ritter** and 30km **Sabine**. It's in the flatter region to the east of these craters that Neil Armstrong made his giant leap into history in 1969.

A gap in Tranquillitatis's border sits above dramatic 101km **Theophilus**. Continuing to the east, there's an irregular rough area where flat lava intermingles with jagged outcrops of highland. Highlights here include the small 50km x 20km mountain range of **Montes Secchi** and the large 56km crater **Taruntius**.

Continue north to where the border approaches Mare Crisium. A finger of dark lava here forms 160km x 100km **Sinus Concordiae**, the Bay of Harmony. Rough highland forms the area to the north of Concordiae, this eventually giving way to flat, dark lava before we meet the gap between Mare Tranquillitatis and Serenitatis again, this time on the eastern side. Here there's a similar pointed feature to Promontorium Archerusia, the 50km x 20km elongated mountain **Mons Argaeus**. Just northeast of this mountain is the **Taurus–Littrow Valley** region, where the last Apollo mission, Apollo 17, landed.

Much to the chagrin of the International Astronomical Union, a number of the features here were named unofficially by the explorers of the time. Consequently features such as Bear Mountain (named after its similarity to a mountain near Silver City, New Mexico, where astronaut Jack Schmitt grew up), Family Mountain and the Sculptured Hills can be found in the region. These were astronaut-named features, as are the craters Frosty, Rudolph and Elves, the latter being a cluster of craters. In case you're wondering; yes, Apollo 17 did take place in December, in the run-up to Christmas!

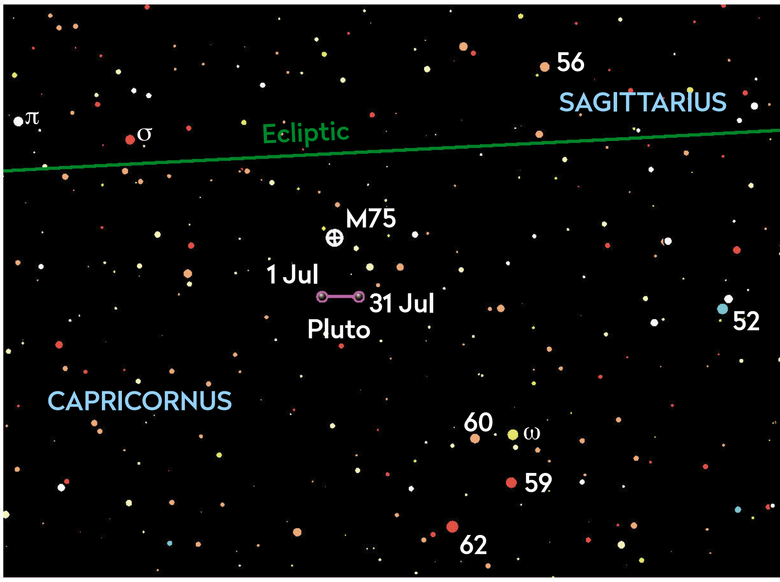
COMETS AND ASTEROIDS

Much-reclassified Pluto reaches opposition on 22 July, east of the Teapot

The term minor planet describes an object in solar orbit which is neither a planet nor a comet, including asteroids. Pluto is neither an asteroid or a comet, although it was once a planet! It was relegated from main planet status in 2006 to become a dwarf planet. Historically, although 'asteroid' and 'minor planet' have been synonymous terms, definitions have become strained as new object discoveries and classifications have occurred. Still designated minor planet 134340, Pluto reaches opposition on 22 July and we're covering it this month despite its classification!

During July, Pluto moves into a barren region of sky to the east of the Teapot asterism in Sagittarius. At an eye-wateringly faint mag. +14.4 and having a relatively low altitude from the UK, you'll need a decent-sized telescope to see it visually – 300mm minimum, although larger will make the task that much easier.

Pluto has a diameter of 2,476km and a 17.2°-inclined, elliptical orbit that takes it out as far as 49.3 AU from the Sun and in as close as 29.7 AU. When it's near to this perihelion, Pluto can be closer than the most distant major planet in the Solar System, Neptune, which orbits the Sun with an average distance of 30.1 AU. Pluto performs this swap once every 248 years, staying closer to the Sun than Neptune for around 20 years. The last time it occurred was between 1979 and 1999.



▲ **Faint Pluto requires a large aperture to observe at opposition**

Being so distant and small, through amateur scopes Pluto never looks anything more than a star-like dot, with its family of five natural satellites well beyond reach. Despite this, locating and recording Pluto remains a popular challenge using amateur equipment. One of the best ways to 'see' Pluto is to use a camera; you can find advice on how to do this on **page 55**.

STAR OF THE MONTH

Sabik, second-brightest star in the Serpent Bearer

Ophiuchius, the Serpent Bearer occupies a large piece of the sky. The 11th-largest constellation by area, its shape is like a box with a roof and legs. Sabik (Eta (η) Ophiuchi) is the star that marks the box's southeast corner (lower left as seen from the UK), where it connects with the eastern leg. In traditional depictions, Sabik marks the position near to one of Ophiuchus's knees.

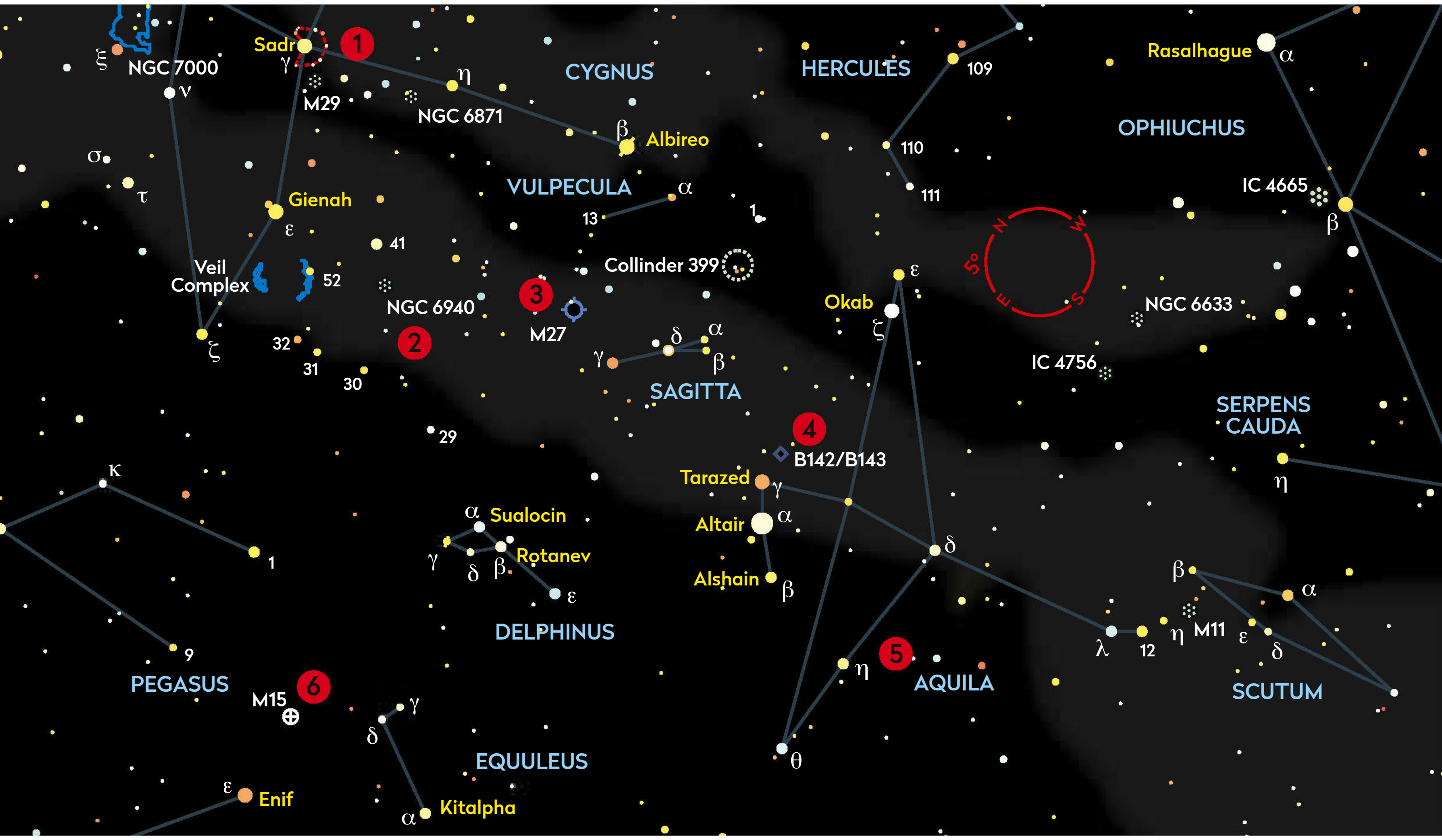
This is a mid-brightness star shining at mag. +2.4, easily visible to the naked eye. The name Sabik is Arabic for 'the preceding one', but why it has this name isn't completely clear. Sabik is a binary with two similarly bright, white components in a mutual 88-year orbit. The stars' brightness and spectral classifications are mag. +3.0, A2 and +3.5, A3. The orbit is quite small, producing a maximum separation of 1.7 arcseconds, and is highly eccentric, bringing the components to within 2 AU when closest and out as far as 65 AU when farthest apart.

To have any chance of splitting the pair, observations need to be made when they are farthest apart (called apastron). Currently they are approaching periastron (closest to one another), which occurs in 2024. The Sabik system is 88 lightyears from the Sun. The two binary components have estimated masses 3 and 3.5 times larger than the Sun. The globular cluster M9 is located 3.5° to the southeast of Sabik, 1° east of the midpoint of the line from Sabik towards mag. +4.4 Xi (ξ) Ophiuchi.

▼ **Sabik is a bright binary pair that's relatively easy to spot but tricky to split**

BINOCULAR TOUR With Steve Tonkin

July's widefield outing includes a heart, a dark 'E' and the original Cepheid variable



1. Sadr, the Heart of Cygnus

10x50 The mag. +2.2 star Sadr (Gamma (γ) Cygni) is sometimes called 'the heart of Cygnus', but it is really only part of the story. If you look carefully, you'll notice that Sadr is merely the point of inflexion in a cardioid-shaped asterism of 11 mostly 6th-magnitude stars. It has a diameter of a little less than 2° and offers a wide variety of colours, from deep orange through yellow and white, to an intense blue-white. ☐ **SEEN IT**

2. NGC 6940

10x50 The open cluster NGC 6940 deserves to be far better known. Use the chart to identify mag. +4.0 41 Cygni and mag. +4.9 30 Vulpeculae and you'll find NGC 6940 between them, appearing like an oval patch of light that extends to the same apparent diameter as the Moon. As you study the 2,700-year-old glow, you should be able to resolve eight or so stars of this very pretty cluster, depending on your sky conditions. ☐ **SEEN IT**

3. The Dumbbell Nebula, M27

10x50 Our next stop is the easiest planetary nebula for binoculars, visible even in moderately light-polluted skies. If you place Gamma (γ) Sagittae at the south of a 5° field of view, the mag. +7.4 Dumbbell Nebula will be just north of centre, looking like a tiny luminous cloud. Initially it will appear rectangular, but with patience you should make out the narrowing in the middle that gives it its common name. ☐ **SEEN IT**

4. Barnard's E Nebula

10x50 In a dark, transparent sky, this pair of dark nebulae, B142 and B143, which you will find 1° west of mag. +2.7 Tarazed (Gamma (γ) Aquilae) is easy to identify because of the rich Milky Way starfield against which it lies. These agglomerations of obscuring gas and dust will appear to you as an uppercase 'E' or an underlined 'C', depending on sky clarity. The easiest bit to see is the middle bar of the E. ☐ **SEEN IT**

5. Eta Aquilae

10x50 What was the first Cepheid variable star to be discovered? Answer: Eta (η) Aquilae (mag. +3.5 to +4.4) – *not* Delta (δ) Cephei, the star that gave its name to this class of variables. Edward Piggott found variability in the former a month before John Goodricke found it in the latter. In 1912, Henrietta Leavitt discovered their period-luminosity relationship – the 'standard candles' Hubble then used to measure galactic distances. ☐ **SEEN IT**

6. M15

15x70 Easy globular cluster M15 is one 15x70 field of view northeast of Delta (δ) Equulei. Don't expect it to look even half as wide (18 arcminutes) as the published data suggests. Most of its stars are in a core so dense that even the Hubble Space Telescope can't resolve it, and only the central 7 arcminutes is visible in 70mm binoculars. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 2

THE SKY GUIDE CHALLENGE

Try to track down tiny minor planet Pluto and then grab a photo of it

Pluto can be a tough target, especially when low in a less than pristine sky. Despite this, trying to locate this tiny world (see **page 53** for more about Pluto) remains a popular challenge with amateur kit. It's currently lying in a barren area on the Capricornus–Sagittarius border, but there are some patterns that will make this month's challenge – to see and record Pluto – a bit easier than you might think.

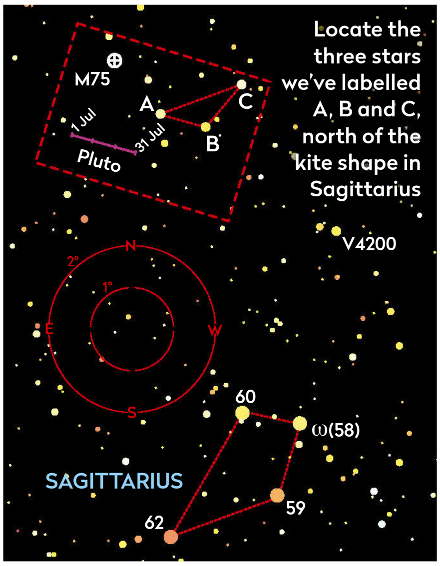
The best way is to use a camera, and you don't need anything fancy. A tracking mount is recommended, although if you don't mind a bit of noise, a high ISO setting may still grab a result even using a static platform such as a tripod.

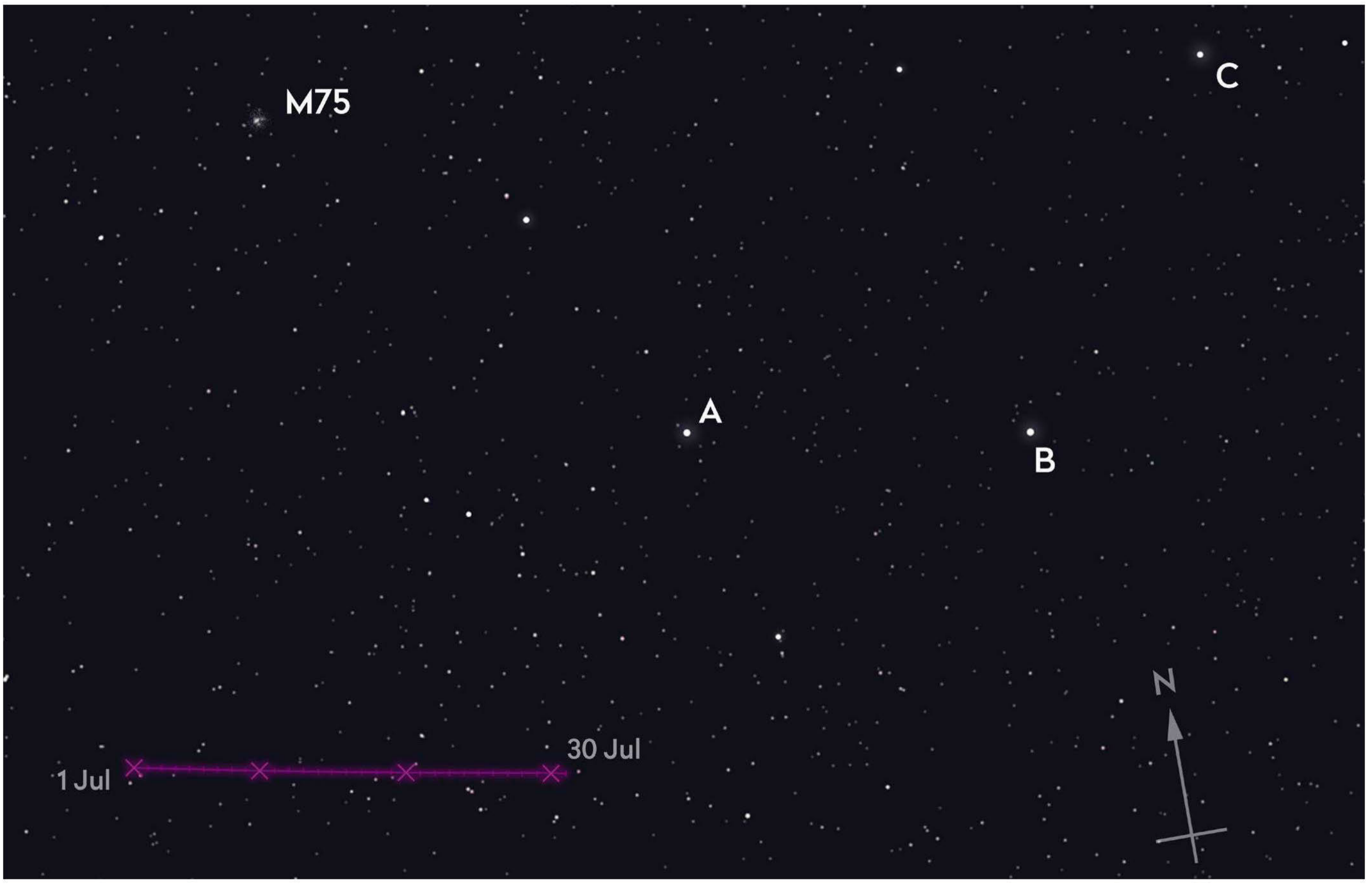
A 200mm or longer lens will capture a decent shot of the Pluto star field. If you can get several shots over separate nights it should be possible to reveal the motion of Pluto by blinking between the images.

The key to locating Pluto in 2023 will be to use a small kite-shaped asterism formed by the stars 58, 59, 60 and 62 Sagittarii. These shine at magnitudes +4.7, +4.5, +4.4 and +4.8 and so aren't particularly hard to see, all being naked-eye stars. Look for them 12° west of the southern tip of Capricornus as marked by mag. +4.1 Omega (ω) Capricorni. Incidentally, 58 Sagittarii is also known as Omega (ω) Sagittarii.

Once you've located this pattern, head north from 62 Sagittarii for 2.5x the length of the kite pattern (62–58 Sagittarii, 2.1°). This will bring you to a triangle of sixth-magnitude stars 1.1° to the southwest of the mag. +8.6 globular cluster M75. The stars are HIP 98785 (mag. +6.4), HIP 98575 (mag. +6.0) and HIP 98399 (mag. +6.8). For ease, let's refer to them as A, B and C respectively. If you extend the line from C to A for the same distance again, you'll arrive where Pluto begins its July track. Throughout the month it covers a distance from its starting point parallel with and of the same distance as A–B.

As long as your camera can cover the area described and can record stars down to mag. +15, you should be able to capture Pluto as a dot. To do this with a general photographic lens, open the lens fully (perhaps closing by a stop or two if the lens distorts badly). Use a mid to high ISO and bracket exposures around, for example, 10, 20 or 30 seconds.





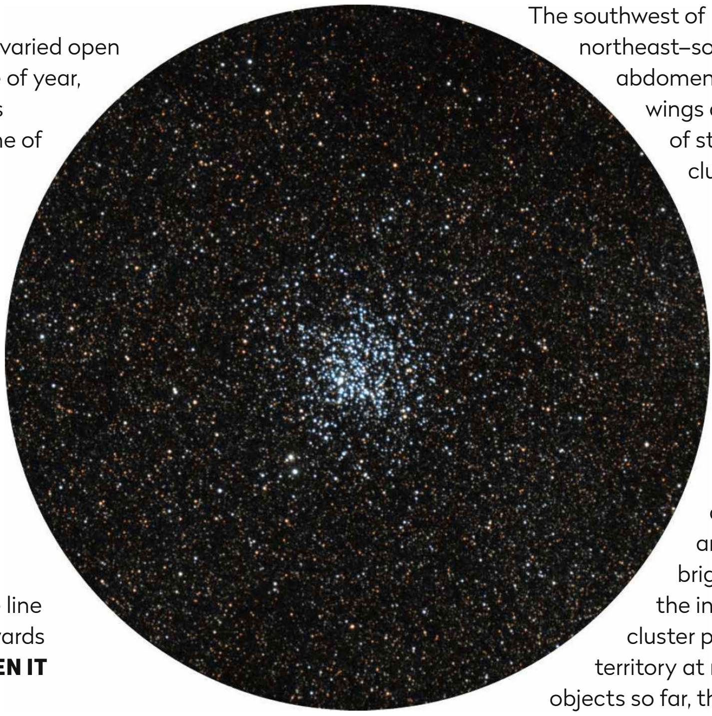
▲ **Globular cluster M75 is a good starting point to find Pluto, whose path is shown here against its 14th-magnitude background star field**

DEEP-SKY TOUR

Spend a warm evening touring these six beautiful, bright, summer star clusters

1 Collinder 399

There are many beautiful, varied open clusters visible at this time of year, but Collinder 399, also known as Brocchi's Cluster, isn't strictly one of them! Informally known as the Coathanger Cluster (under low power it forms the shape of a clothes hanger), this is not a true cluster but just an amazingly fortuitous line-of-sight pattern or asterism. Analysis of the 'object' revealed only six of the brighter stars shared common motion properties. It's around 1.7° wide, 0.5° high and visible to the naked eye given good eyesight. It sits two-thirds of the way along the line from Vega (Alpha (α) Lyrae) towards Altair (Alpha (α) Aquilae). ☐ **SEEN IT**



▲ **Don't miss our sixth target, the Wild Duck Cluster, M11, a simply stunning and massive collection of thousands of blue-white stars**

MARKUS BLAUENSTEINER/CEDIC TEAM/CCDGUIDE.COM, CHART BY PETE LAWRENCE

2 IC 4756

Our next target brings us into true cluster territory. IC 4756 is located in Serpens, 4.5° west and 1° north of mag. +4.6 Ayla (Theta^1 (θ^1) Serpentis). Alternatively, extend a line from the Coathanger Cluster through mag. +3.0 Zeta (ζ) Aquilae for a little over the same length again. IC 4756 has several names including Graff's Cluster and the Tweedledee Cluster as it's paired with NGC 6633 (below). It's also sometimes referred to as the Secret Garden Cluster. It's a large object with an apparent diameter of 1°. It sits in the open part of a wedge pattern formed from stars between mag. +7.0 and +6.3. The cluster is best suited for low powers. With an integrated magnitude of +4.6, it can be seen with the naked eye. ☐ **SEEN IT**

3 NGC 6633

The Tweedledum Cluster, NGC 6633 lies 3° north-northwest of IC 4756, a small distance but enough to put it across the border into Ophiuchus. Like IC 4756, NGC 6633 has several informal names, including the Captain Hook Cluster and Wasp-Waist Cluster. It appears half-a-degree across and like IC 4756 has an integrated magnitude of +4.6. A small scope shows around a dozen stars brighter than 10th magnitude. The region is very star-rich, hiding the true nature of both clusters. The southwest of NGC 6633 forms an elongated northeast–southwest teardrop, the abdomen of the 'wasp'. The insect's wings are represented by a thin wedge of stars heading northeast from the cluster centre. ☐ **SEEN IT**

4 IC 4665

Bright open cluster IC 4665 lies 10.3° west and 1.2° south of IC 4756, although it's easier to find from mag. +2.8 Cebalrai (Beta (β) Ophiuchi), 1.3° to the southwest. IC 4665 is a large coarse open cluster at 70 arcminutes across and contains around 30 member stars. The brightest shines at mag. +6.9, but the integrated magnitude of the cluster places it well within naked-eye territory at mag. +4.2. As with all the objects so far, the best way to observe IC 4665 using a telescope is with a low-power eyepiece. Sometimes referred to as the Summer Beehive, with a good imagination you may be able to pick out the word 'HI' created by the cluster's stars. ☐ **SEEN IT**

5 Collinder 350

Our penultimate target is arguably the hardest. It's bright at mag. +6.1 and large with an apparent diameter of 39 arcminutes, but it's also very sparse and easy to pass over without realising you've seen it. It is located approximately 1° south of mag. +3.8 Gamma (γ) Ophiuchi, itself 2.1° south-southeast of Cebalrai. Two brighter stars sit either side of the cluster: mag. +7.5 HIP 87244 and +6.6 HIP 86969. The cluster sits southwest of a 'lobe' of the Milky Way extended towards Ophiuchus, Collinder 350's size and sparse appearance helping it to camouflage into the background. Using a low power, a small scope will reveal around 15 members of this cluster. ☐ **SEEN IT**

6 M11

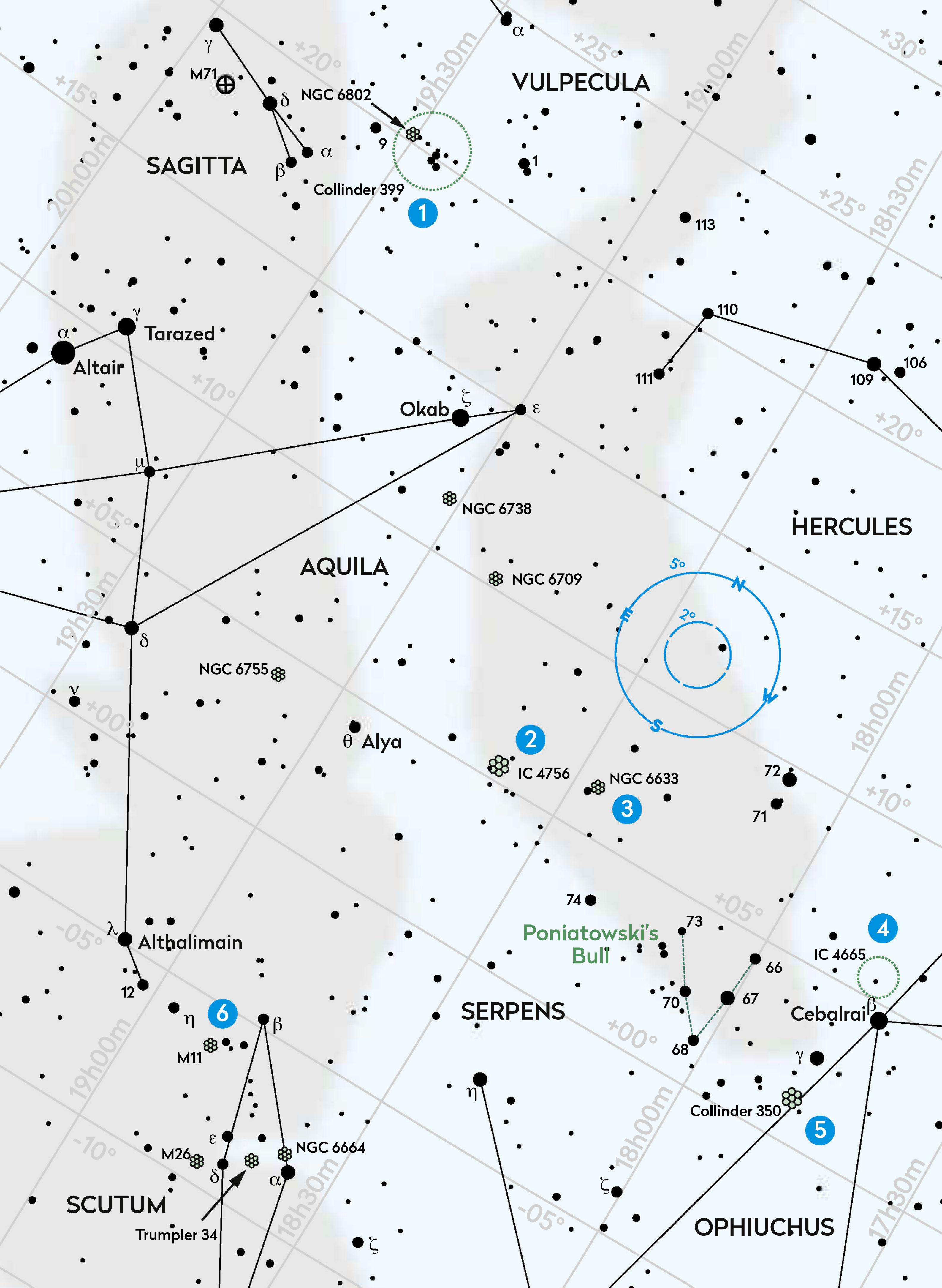
No tour of bright summer open clusters would be complete without a visit to the spectacular Wild Duck Cluster, M11. This is easy to find by continuing the arc of stars at the southern end of Aquila: mag. +4.4 Althalimain (Lambda (λ) Aquilae), mag. +4.0 12 Aquilae and mag. +4.8 Eta (η) Scuti. A 150mm scope will show around 150 stars, the brightest around 11th magnitude. The stars appear clumped together with dark lanes between the clumps, almost as if something has cracked the cluster into pieces. Larger apertures offer a stunning view of M11's 2,900 or so stars, 500 of which are brighter than 14th magnitude. ☐ **SEEN IT**

This Deep-Sky Tour has been automated

ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions



VULPECULA
SAGITTA
AQUILA
HERCULES
SERPENS
SCUTUM
OPHIUCHUS
M71
NGC 6802
Collinder 399
Tarazed
Altair
Okab
NGC 6738
NGC 6709
NGC 6755
Alya
IC 4756
NGC 6633
Poniatowski's Bull
Althalimain
Cebalrai
IC 4665
Collinder 350
M11
M26
NGC 6664
Trumpler 34
1
2
3
4
5
6
5°
2°
N
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+30°
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AT A GLANCE How the Sky Guide events will appear in July

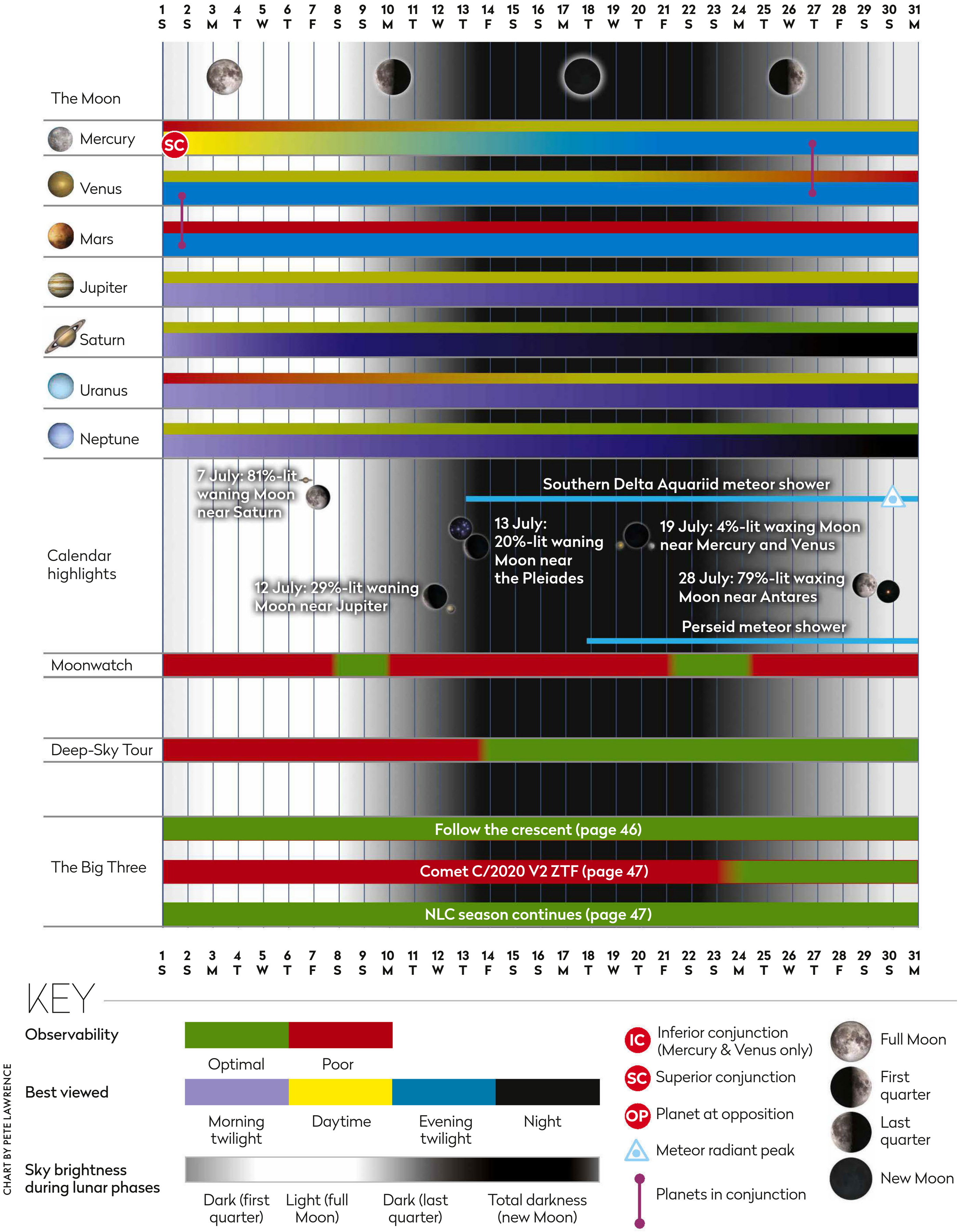

CHART BY PETE LAWRENCE

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Trustpilot
Photography can
Change
the way we see
the world.
Together, let's change the bigger picture. MPB puts cameras and lenses into more hands, more sustainably.
The platform to buy and sell used photo and video kit.
#ChangeGear
Buy•Sell•Trade
Create

Stargazing in Utah *the darkest state*

Jamie Carter marvels at the night sky above Utah, a state packed with internationally-recognised dark-sky sites, iconic astrophoto locations and a long history of indigenous astronomy

The Sun had set by the time we pulled into a parking lot just outside Moab, Utah. This is where we agreed to meet our host for an evening under the sky and, sure enough, we arrive to find a convoy of four cars waiting for us. At the front was a large station wagon with decals on it that gave away the subject of this night-time expedition: "Have telescopes, will travel!"

We followed the convoy along lonely roads before parking in La Sal Mountains Viewpoint in eastern Utah's canyonlands. The station wagon was already there. It belonged to our host, Alex Ludwig at RedRock Astronomy, who was already unloading collapsible chairs and parts of the mount for a 9.25-inch refractor.

"Let's set up by this bush – it will help reduce the wind," says Ludwig as we construct a crescent of chairs around the telescope. But I can't take my eyes off something twinkling due west across the fast-fading red rock landscape: it's Mercury – a planet I've seen only a handful of times – shining brightly, barely a degree above the horizon. Above it is bright Venus and the Pleiades, Aldebaran and the stars of Orion. But there's something strange about them. They're not twinkling. They glow. We're on high ground here, about a mile up, and it shows. Utah can take your breath away in more ways than one.

Out into star country

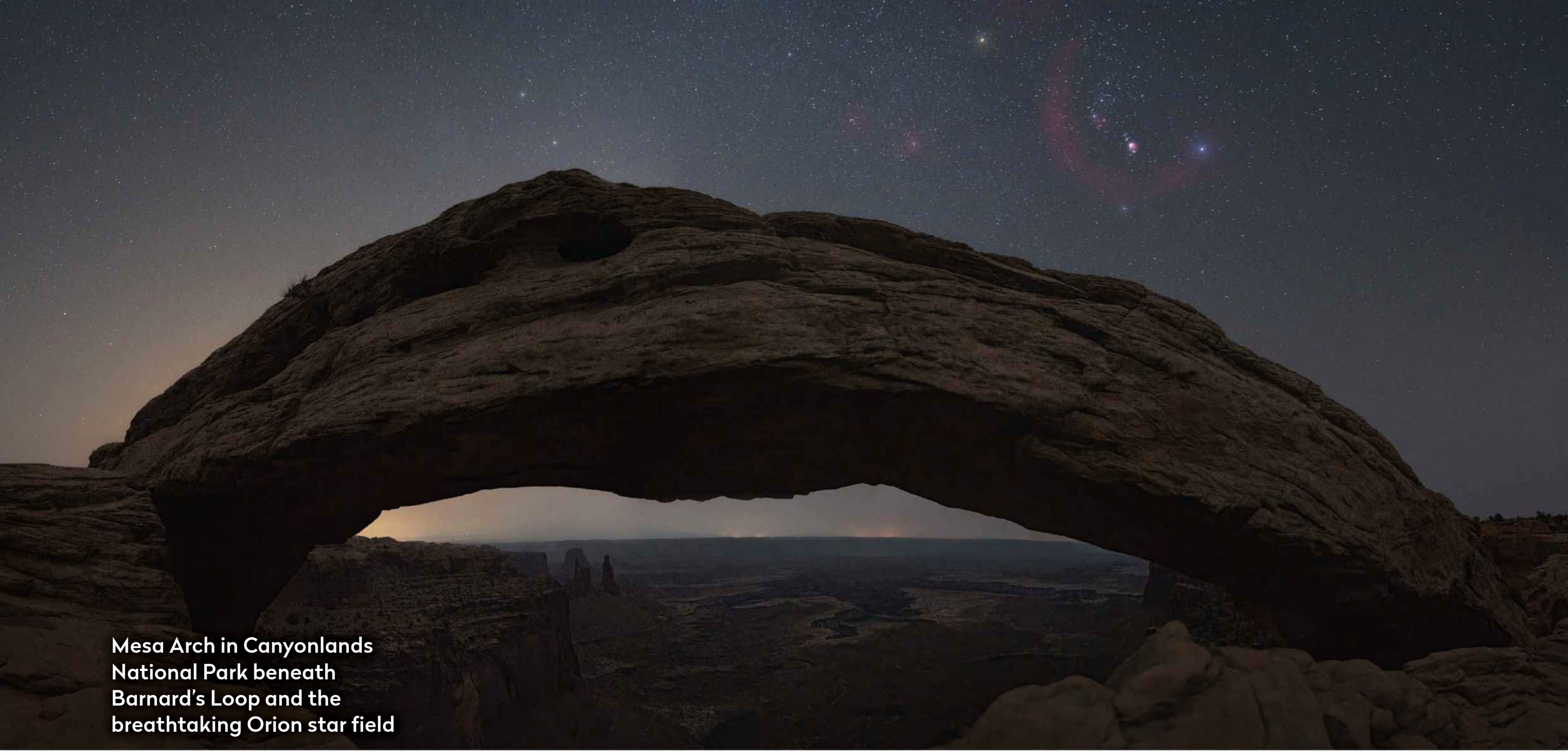
Aside from Utah having the highest concentration of certified International Dark Sky places in the world – there are ▶

Ready to roll: Jamie's convoy heads out in search of stars

Taking in the desert sky's crystal-clear views

JAMIE CARTER X 2, BETTYMAYA FOOTT

Gloriously star-spangled skies above Delicate Arch in Arches National Park, Utah



Mesa Arch in Canyonlands National Park beneath Barnard's Loop and the breathtaking Orion star field

▶ 24 spread across the state – Utah's high elevation and resulting thin air is a major reason why it's a dream dark-sky destination. The state occupies a large part of the Colorado Plateau, a high desert zone that centres on the Four Corners region of the southwestern US: Utah, Colorado, Arizona and New Mexico.

"The higher you go, the clearer it's going to be and the more you see," says Ludwig about Utah's position above the warmest, densest part of Earth's atmosphere. He hands out blankets as I reach for my gloves, my hands already cold from clutching my binoculars. The Utah desert around here gets cold at night all year, but even colder – and clearer – elsewhere in Utah. Ludwig tells me that Bryce Canyon, one of the most popular national parks in the US, reaches 2,700 metres elevation.

Utah has some of the darkest night skies visible anywhere in the world. The easiest places to go are, of course, the vast network of International Dark Sky Parks. It's the national parks – Arches, Canyonlands, Bryce, Zion and Capitol Reef – that get the most attention, but don't overlook the state parks. Spread across the state, these tend to have better and cleaner camping facilities than their larger siblings, with the pick of the International Dark Sky Parks being Antelope Island, Dead Horse Point, Goblin Valley, Goosenecks and Kodachrome.

Utah is also one of the best places for capturing the Milky Way in North America, but it matters when you go. The best time for astrophotography is around the new Moon, when the skies are as dark as possible, but late March to June has milder temperatures, clear skies and the Milky Way rising in the night sky.

Photo op heaven

Canyonlands National Park has perhaps the biggest draw of all for astrophotographers in the form of Mesa Arch, which is an easy 10-minute walk from a parking area.

"Everybody wants to get the Milky Way above it in May, or the sunrise through it,"

Navajo constellations

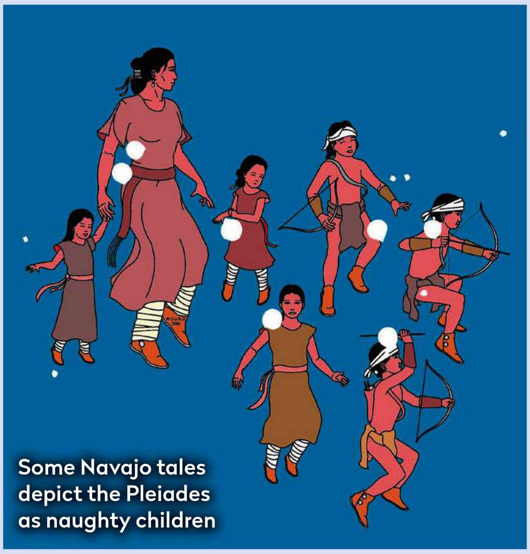
The dark skies hold great importance for one of the region's native tribes

Utah gets its name from the Ute tribe, although it's been inhabited for thousands of years by various tribes, including the Puebloans and the Navajo. These local cultures interpret the night sky in their own way.

"For a lot of the tribes here, the area around Polaris, the North Star, is a family hearth, with a mother figure on one side and the hunter-father on the other side," says RedRock Astronomy's Alex Ludwig.

The Navajo word for constellations is So'Dine'é, meaning Star People, and like many cultures around the world, they are closely linked with the people's history and mythology. The Big Dipper is known as the Male Revolving One (Náhookòs Bi'kà'), who protects and leads his people. The stars of Cassiopeia form his counterpart, the Female Revolving One (Náhookòs Bi'áád), who represents growth, harmony and stability. Together, they turn around the Central Fire, Polaris (Náhookòs Bikò').

The Pleiades asterism, known as Dilyéhé, acted as a timekeeper for the Navajo, as the timing of its disappearance from the evening night sky in May to its reappearance in June or July marked out the planting season. This purpose was represented in one story about the cluster, which saw the stars as seven youths who would sneak out and steal people's seeds, leading to the traditional saying "Don't let Dilyéhé steal your seeds".



Some Navajo tales depict the Pleiades as naughty children

RYAN ANDREASEN/NIGHTSKYSCIENCE.COM, CHINLE UNIFIED SCHOOL DISTRICT, MAP BY PAUL WOOTTON, DON GRALL/ISTOCK/GETTY IMAGES

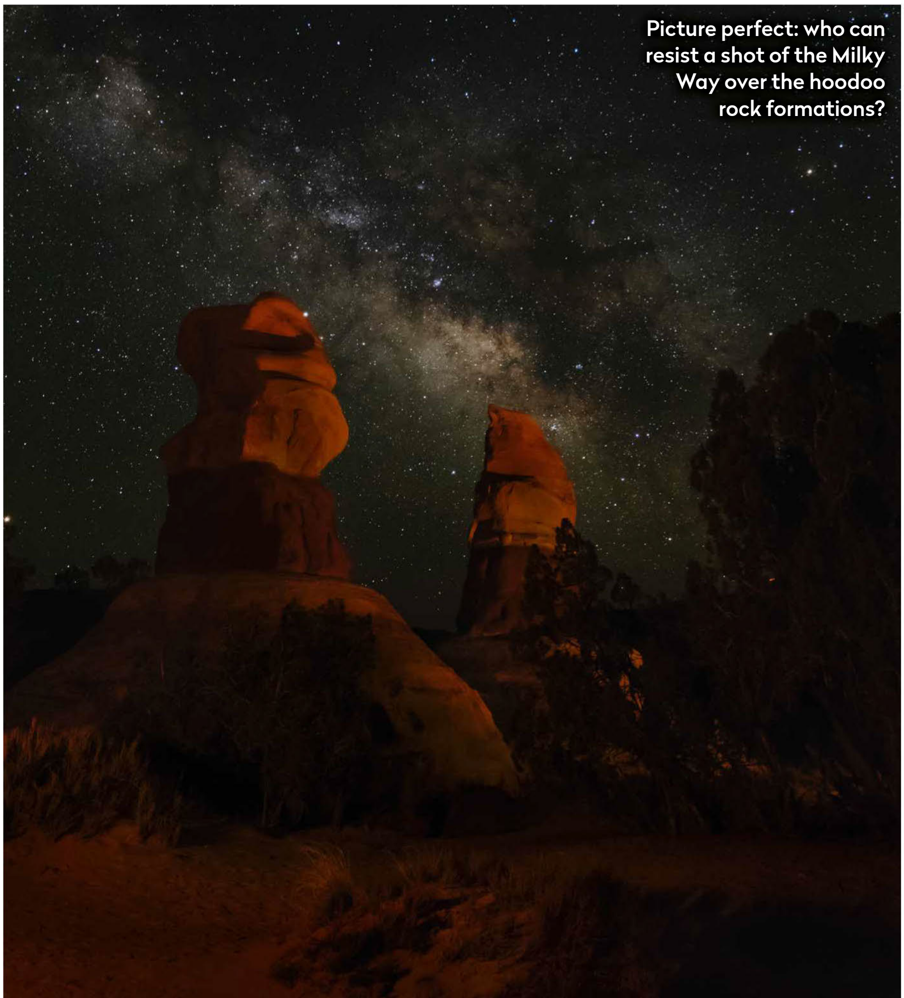
STATE FORESTS

NATIONAL PARKS (NP)

Utah's dark sky sites

Certified stargazing locations across the state

1. Antelope Island State Park
2. Arches National Park
3. Bryce Canyon National Park
4. Canyonlands National Park
5. Capitol Reef National Park
6. Cedar Breaks National Monument
7. Dead Horse Point State Park
8. Dinosaur National Monument
9. East Canyon State Park
10. Fremont Indian State Park
11. Goblin Valley State Park
12. Goosenecks State Park
13. Helper (town)
14. Hovenweep National Monument
15. Jordanelle State Park
16. Kodachrome Basin State Park
17. Natural Bridges National Monument
18. North Fork Park
19. Rainbow Bridge National Monument
20. Rockport State Park
21. Steinaker State Park
22. Timpanogos Cave National Monument
23. Torrey (town)
24. Zion National Park



Picture perfect: who can resist a shot of the Milky Way over the hoodoo rock formations?

says Ryan Andreasen, a Utah-based dark-sky activist at NightSkyScience.com who volunteers for the International Dark Sky Association. "You do get people jostling for position, but everyone can get a good shot if they work together." He advises befriending other photographers because space is tight in front of Mesa Arch.

"Arches National Park is a paradise for astrophotographers, with endless rock formations and otherworldly landscapes," says Dan Zafra from CaptureTheAtlas.com, who organises astrophotography tours to Utah. "Goblin Valley State Park feels like being on another planet, while Grand Staircase-Escalante National Monument and Natural Bridges are more remote and offer excellent opportunities to do astrophotography in unique locations."

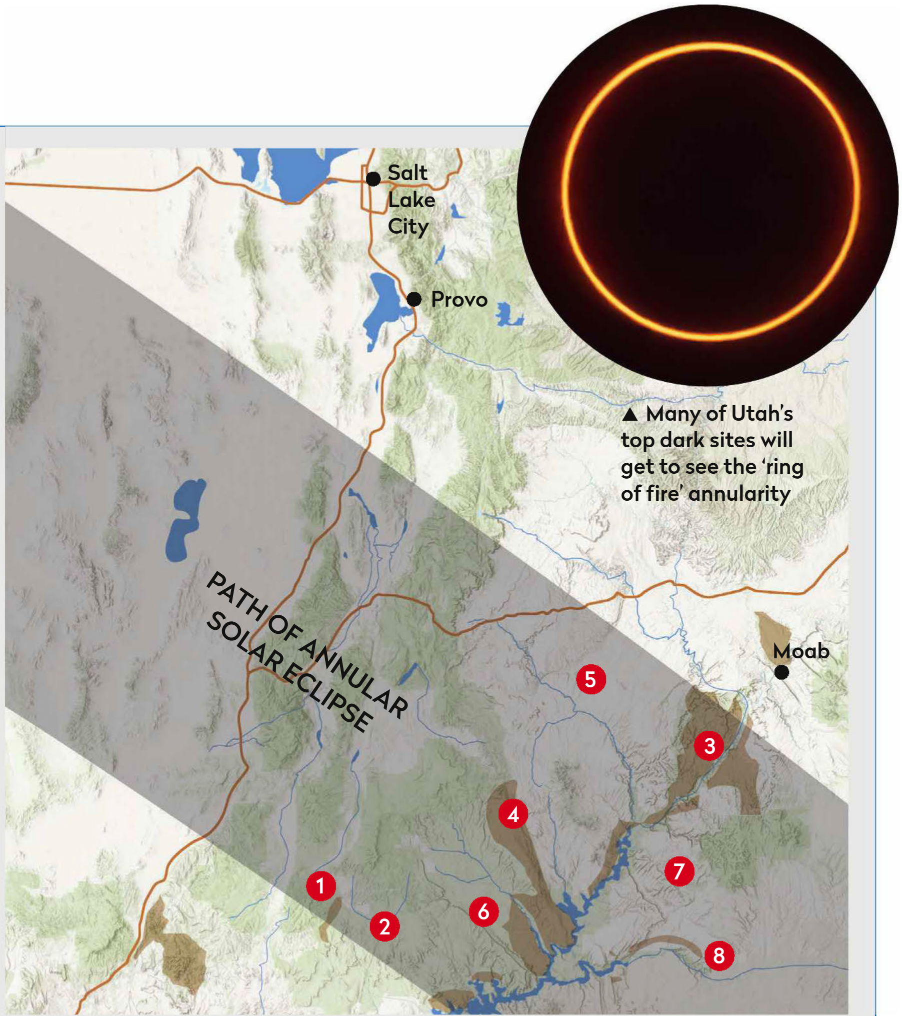
Wherever you head, always follow the regulations. Although all national parks are accessible at night, light painting – where you illuminate the foreground with a torch during a long-exposure shot – is banned in Canyonlands and Arches, to prevent astrophotographers from ruining each other's shots. ▶

▶ "I recommend planning and arriving well in advance to grab a good spot if you aim to do astrophotography," says Zafra.

If you're after a unique astrophoto of the Milky Way above red rock formations, or you want to try some deep-sky astrophotography, then there are numerous other options in Utah. There's no 'right to roam', but 71 per cent of the state is public lands managed by federal or state agencies. "If you want to do your own thing, just go to the backcountry," says Ludwig. An easy way of accessing it is to find a remote campground, which are common inside and outside of the parks. A great option is land owned by the Bureau of Land Management (nearly 22.8 million acres in Utah, about 42 per cent of the entire state) or the Forest Service (8.2 million acres and seven national forests). The bureau manages all lower-grade land and once you get above a certain altitude, which tends to be around a mile high, the Forest Service takes charge.

Crowd control

While Utah currently has some of the most protected dark skies and public lands in the US, its population of 3.4 million is growing, particularly along a strip of flat land to the west of the Wasatch Mountains that locals call the 'Wasatch Front'. "People are discovering Utah – we've had record-breaking population growth on that Wasatch Front in the last couple of years," says Andreasen. "It's why we're working hard to see if we get some lighting controls in place before it really blows up."



▲ Many of Utah's top dark sites will get to see the 'ring of fire' annularity

Utah's ring of fire

An annular eclipse will pass over Utah in October

The new Moon is the perfect time to visit Utah for some stargazing, but in October 2023 that window of opportunity brings a unique bonus. On Saturday 14 October, the new Moon will pass in front of the Sun to cause an annular solar eclipse. The Moon will cover only 90 per cent of the Sun as it will be slightly further from Earth than normal, resulting in a 'ring of fire' that will last around five minutes. The path of annularity crosses from Oregon over to Texas before exiting the US, passing over many International Dark Sky Parks in Utah:

1. Bryce Canyon National Park (annularity duration 2 minutes 15 seconds); **2.** Kodachrome Basin State Park (2 minutes 29 seconds); **3.** Canyonlands National Park (2 minutes 24 seconds); **4.** Capitol Reef National Park (4 minutes 37 seconds); **5.** Goblin Valley State Park (2 minutes 54 seconds); **6.** Grand Staircase-Escalante National Monument (3 minutes 19 seconds); **7.** Natural Bridges National Monument (4 minutes 28 seconds); **8.** Goosenecks State Park (4 minutes 40 seconds)

Locals are keen to protect dark sites like Antelope Island from the state's population boom

Perhaps most at risk is Antelope Island State Park to the west, which overlooks the Great Salt Lake and is just an hour-and-a-half drive from Salt Lake City. Go northeast of Salt Lake City through the mountains and you'll find Ogden Valley, an oasis of dark stretching from North Fork Park to Huntsville, a tiny, peaceful town with few lights. I watched a dramatic sunset between two tipis in the grounds of the Compass Rose Lodge, where we were staying, before the stars came out. They even had their own observatory, the HALO (Huntsville Astronomic and

MAP BY PAUL WOOTTON, RYAN ANDREASEN/NIGHTSKYSCIENCE.COM X 2, MICHAEL VER SPRILL/ISTOCK/GETTY IMAGES, PIRIYA PHOTOGRAPHY/ISTOCK/GETTY IMAGES, ELOI_OMELLA/ISTOCK/GETTY IMAGES, COMPASS ROSE LODGE

Where to go: Utah's top dark-sky spots

Our pick of the best locations for stargazing and astrophotography

▲ Arches National Park

A three-hour drive from Salt Lake City, this iconic park is so popular you'll need a timed entry ticket to visit during the day, but at night it's both open and empty. Top stargazing spots include Balanced Rock, The Windows, Delicate Arch and Devils Garden Trail towards Landscape Arch.

▼ Canyonlands National Park & Dead Horse Point State Park

These adjacent parks have incredible views from the high plateau across deep canyons, pinnacles, cliffs and spires carved by the Green and Colorado Rivers. Don't miss Mesa Arch, Upheaval Dome and Grand Viewpoint Overlook in Canyonlands, and Dead Horse Point Overlook.

▲ Bryce Canyon National Park

This small park has thousands of tall red-rock spires known as hoodoos, best seen from Inspiration Point, Sunset Point and Sunrise Point. The visitor centre offers an astronomy programme and there's an astronomy festival in June. The quieter Kodachrome Basin State Park is very close.

▼ Goblin Valley State Park

Thousands of colourful mushroom-shaped hoodoos – called goblins – make this remote park a unique place for astrophotography, due to its other-worldly feel. Its location between Capitol Reef and Canyonlands National Park makes it a great stop on a road trip across southern Utah.

Compass Rose Lodge in Huntsville even has its own observatory offering guided tours

Lunar Observatory) where guests can get a guided tour of the night sky through a 16-inch Ritchey–Chrétien telescope. I've watched the Moon for decades, but never seen its craters in such stunning detail.

May is perfect for seeing the Milky Way above the red rocks, while a March trip means you can get some skiing in during the day if you wish. If you come during the late spring, summer and early autumn, book well ahead and expect crowds, particularly in Zion, Bryce and Arches. But if you're after an audience with the stars, then Utah has endless possibilities.

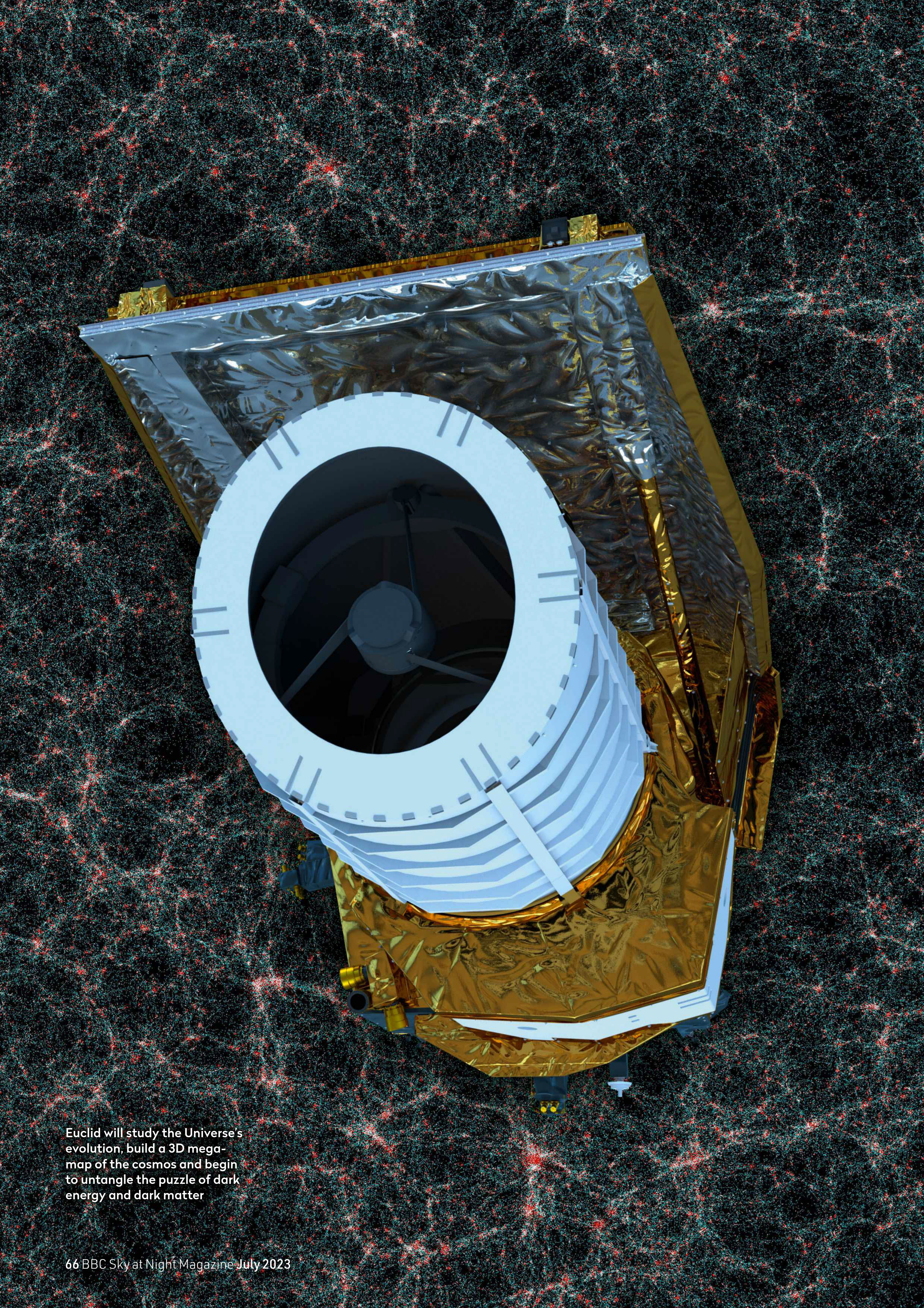
"I do prefer to find places that nobody really goes," says Andreasen, who has worked as an astrophotographer for the Utah State Park Service. "To be able to go into these areas and connect with the night sky without anyone else around is just phenomenal – and it excites me every time I return," he says. Even those who live under it never get tired of the dark skies found over Utah.

Jamie's trip was paid for by VisitUtah.com

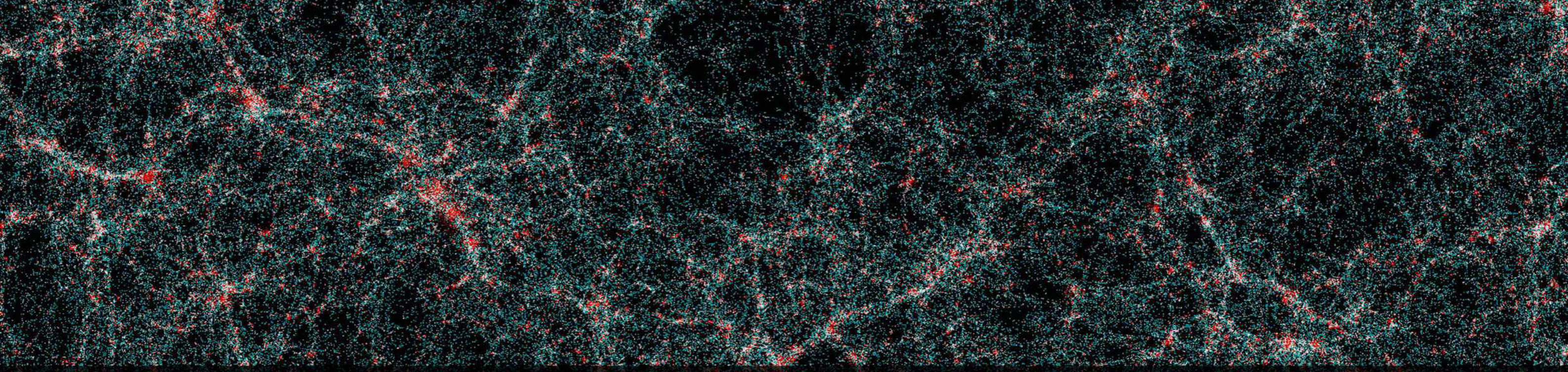
Astro tourism in Utah

Bureau of Land Management **www.blm.gov**
USDA Forest Service **www.fs.usda.gov**
International Dark-Sky Association **www.darksky.org**
America's Scenic Byways **scenicbyways.info**
RedRock Astronomy, Moab **moab-astronomy.com • call (001) 435-210-0066**
Compass Rose Lodge & HALO Observatory, Huntsville **www.compassroselodge.com • call (001) 385-279-4460**
Dark Ranger Telescope Tours, Bryce Canyon **www.darkrangertelescopetours.com • call (001) 435-590-9498**

Jamie Carter is a science writer and the author of *A Stargazing Program for Beginners: A Pocket Field Guide*



Euclid will study the Universe's evolution, build a 3D mega-map of the cosmos and begin to untangle the puzzle of dark energy and dark matter



Euclid

Shedding light on the dark Universe

A new European space telescope launching this month will tackle the mysteries of dark matter and dark energy, reports **Govert Schilling**

Leaf through this issue of *BBC Sky at Night Magazine*, look at the numerous eye-catching photographs and marvel at the beauty of the cosmos. Then realise that everything we can see with astronomical telescopes – stars, nebulae, galaxies – amounts to a mere 5 per cent of the total content of the Universe. The remaining 95 per cent is composed of two mysterious components: dark energy – the 'force' behind the accelerating expansion of the Universe – and dark matter. We know they exist, but their true nature eludes us.

Enter Euclid, the next space mission in the Cosmic Vision science programme of the European Space Agency (ESA). Due to launch into space in the first half of July from Cape Canaveral in Florida, this ambitious space telescope will focus on the dark Universe by mapping and studying no less than two billion galaxies. "Nothing like this has ever been done before," says Euclid's independent legacy scientist Ivan Baldry of Liverpool John Moores University.

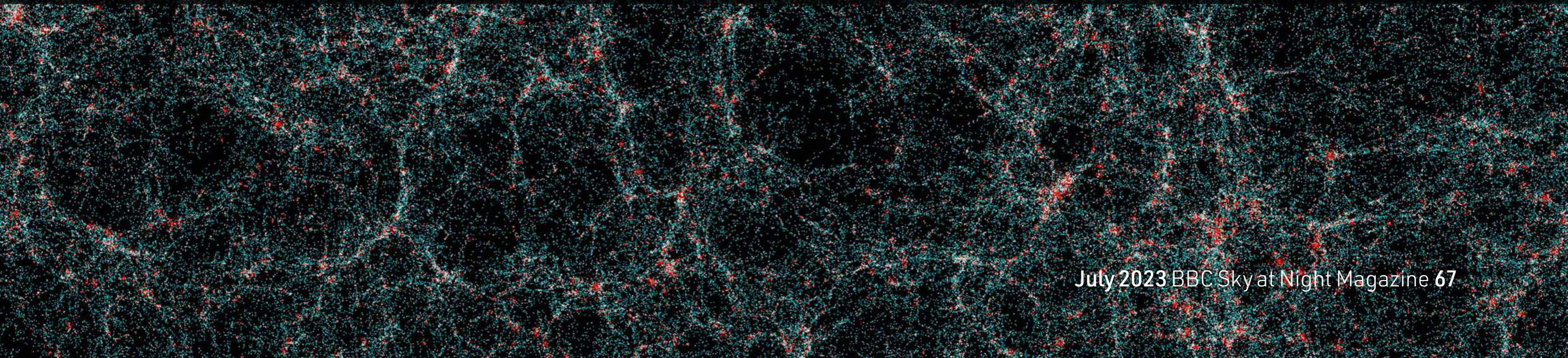
Euclid's observations will reveal the expansion history of our Universe (which is governed by dark energy) and the three-dimensional distribution of mass (which mainly consists of dark matter). As a bonus, the mission will check whether Albert Einstein's general theory of relativity is the right formulation of gravity on cosmic scales. According to project manager Giuseppe Racca at ESTEC (ESA's science and technology centre in Noordwijk, the Netherlands), "This combination is the unique selling point of Euclid".

The road to launch

The Euclid mission was selected in 2011 and formally adopted by ESA in the summer of 2012. NASA became a partner in the project in early 2013. At present, the Euclid consortium has about 2,000 members from 13 European countries plus the United States.

The original plan was to launch the spacecraft from French Guiana on a Russian Soyuz rocket in late 2022, but after Russia invaded Ukraine, the ►

ESA/ATG MEDIALAB; J. CARRETERO (PIC) P. TALLADA (PIC) S. SERRANO (ICE) AND THE EUCLID CONSORTIUM COSMOLOGICAL SIMULATIONS SWG



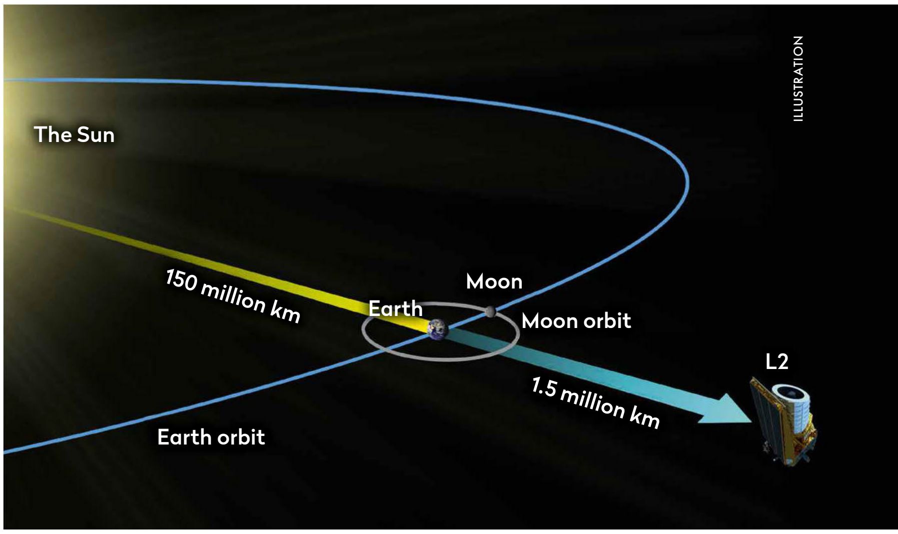
In the pipeline since 2011, Euclid was delayed by the war in Ukraine and will now launch on a SpaceX Falcon 9

▶ cooperation between ESA and the Russian space agency Roscosmos was suspended, and Euclid found itself in need of an alternative launcher. Before long, given the repeated delays of the ongoing development of the European Ariane 6, the choice fell on the commercial Falcon 9 rocket of Elon Musk's SpaceX.

"We had to get used to a whole different working environment," says Racca. "At SpaceX, I hardly met anyone who was older than my own children," he quips. Meetings were held without detailed minutes being kept. Changes in the launch strategy to accommodate the relatively low mass of Euclid were made almost overnight. But it all went very smoothly and fast. "Yes, I've been worried," Racca admits, "but I'm confident nevertheless. After all, the Falcon 9 has only had two failures on more than 200 launches."

The Euclid spacecraft was constructed by Thales Alenia Space in Italy. Measuring 4.5 metres tall and 3.1 metres in diameter, the launch mass is about two tonnes. The payload module, built by Airbus Defence and Space in France, consists of a 1.2-metre telescope (with an optical quality superior to anything like it, according to Racca) and two scientific instruments: a camera operating at visible wavelengths (VIS) and a near-infrared spectrometer and photometer (NISP).

During the six-year mission, the 600-megapixel VIS camera will capture Hubble-quality images of one-third of the sky, with a field of view of half a square degree: about twice the apparent size of the full Moon. Meanwhile, NISP will measure the brightness and the accurate shape of about 1.5 billion galaxies in three near-infrared wavelength bands, and take detailed spectra of some 25 million bright galaxies.



ILLUSTRATION

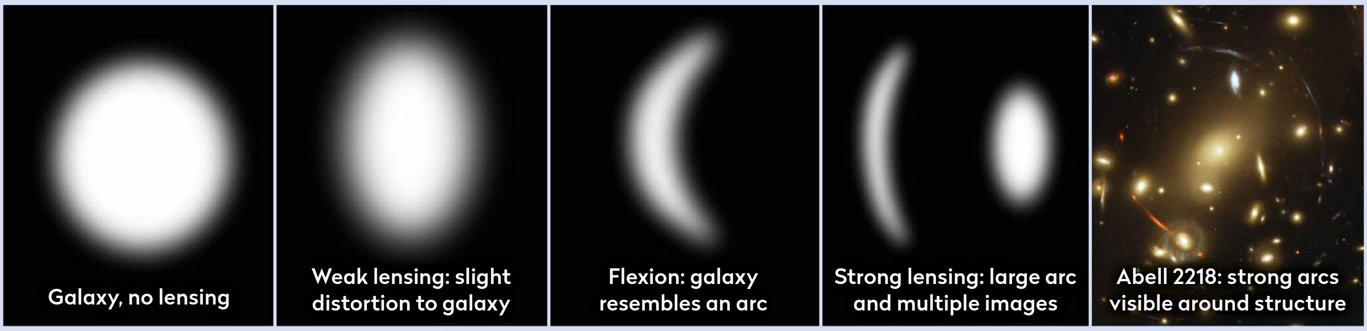
▲ Like the James Webb Space Telescope, Euclid will conduct its science from Lagrange point L2, 1.5 million kilometres out from Earth

After launch, Euclid will take about a month to reach its halo orbit around the second Lagrange point, 1.5 million kilometres beyond Earth as seen from the Sun, in the same region of space as the James Webb Space Telescope. Once per day it will transmit up to 850 gigabits of data to ESA ground stations in Argentina and Spain.

Making a 3D inventory of space

Like a cosmic version of Google Maps, Euclid will provide astronomers with the most comprehensive three-dimensional inventory of the Universe ever. What ESA's Gaia mission (launched in 2013) did for the majority of stars in our Milky Way Galaxy, Euclid will do for a huge number of galaxies in the wider Universe: precisely determine their position

ESA–S. CORVAJA, ESA, NASA/ESA AND JOHAN RICHARD (CALTECH/USA), ESA/GAIA/DPAC/EUCLID CONSORTIUM/ACKNOWLEDGMENT: EUCLID CONSORTIUM SURVEY GROUP



▲ Lensing – the distortion of galaxies by an invisible foreground mass – is the giveaway clue for dark matter that Euclid is looking for

Weak lensing: a primer

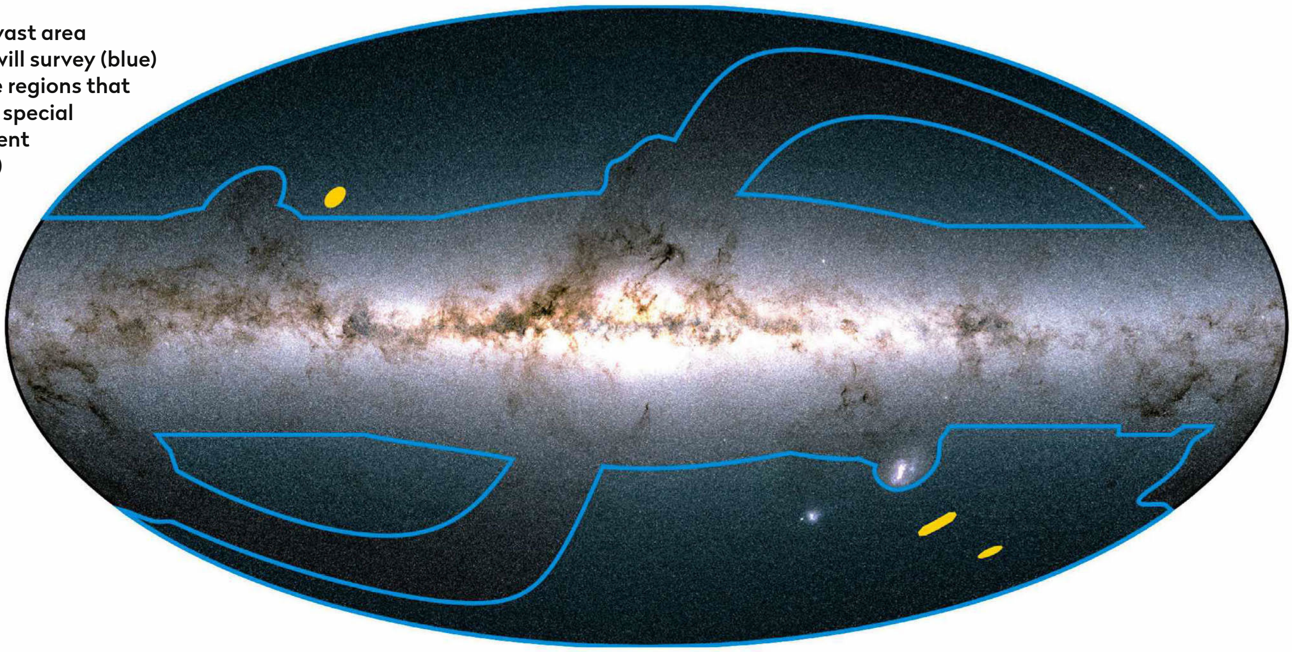
How do you find something invisible? Look for its gravitational effect on space-time

Through weak gravitational lensing, we can estimate how much gravitating mass – including dark matter – is in a region of space. That's because this foreground mass slightly magnifies and stretches the images of faint, remote background galaxies. The amount of distortion tells you how much mass produces the lensing.

This is not as simple as it sounds, though. Galaxies already have elongated shapes, both because they're generally flattened and because we don't always see them face-on. So with just one galaxy, it's impossible to distinguish how much of its observed shape and orientation is due to weak lensing. Instead, astronomers study as many background galaxy images as possible, looking for a tiny departure from the expected random distribution of galaxy orientations.

So here's the general idea: observe hundreds (or thousands, or even millions) of faint background galaxies. Check for departures from random orientations. Use these departures to map the strength of the weak lensing effect that's responsible for the minute distortions. Then derive the corresponding mass distribution in the foreground. Hey presto, you've just arrived at a mass map of part of the Universe.

▶ The vast area Euclid will survey (blue) and the regions that will get special treatment (yellow)



on the sky, their shape and their distance. How will it do this? Well, a galaxy's distance follows from its so-called redshift: the longer the light from a galaxy has travelled through expanding space to reach our telescopes, the further the light waves are stretched to longer wavelengths, corresponding to a redder colour. For the 25 million brightest galaxies observed by Euclid, the redshifts can be directly measured from the spectra obtained by NISP.

For 1.5 billion fainter and more distant galaxies, for which no detailed spectra are available, Euclid's near-infrared measurements are combined with at least four brightness measurements at various optical wavelengths, obtained by existing large ground-based telescopes such as the Canada-France-Hawaii Telescope, Subaru Telescope and Pan-STARRS (all in Hawaii), and by the future Vera Rubin Observatory in Chile. From the resulting spectral energy distribution, astronomers can deduce a photometric redshift, albeit less precise than NISP's results.

As Euclid's project scientist René Laureijs at ESTEC explains, mapping the three-dimensional distribution of galaxies at different redshifts sheds light on the cosmic expansion history. After all, ▶

Mapping out the Universe

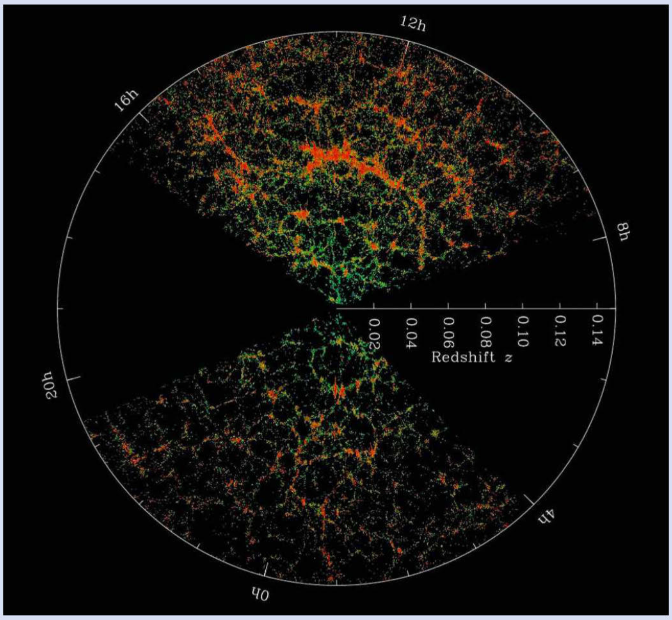
Euclid's incredible 3D cosmic cartography is the latest attempt at a roadmap of space

The first three-dimensional map of the Universe, made with a 1.5-metre telescope at Mount Hopkins in Arizona, was published over 40 years ago, in 1982. It took Marc Davis and his colleagues five years to determine the redshifts and corresponding distances of 2,400 galaxies, out to a distance of approximately 600 million lightyears. A second redshift survey of the same wedge of sky, carried out between 1985 and 1995, mapped the 3D positions of no fewer than 18,000 galaxies.

Between 1997 and 2002, using multi-object spectroscopy at the 3.9-metre Anglo-Australian Telescope, a team led by Matthew Colless carried out the Two-Degree-Field (2dF) Galaxy Redshift Survey. They determined the redshifts of 230,000 galaxies, out to a distance of some 2.5 billion lightyears.

The Sloan Digital Sky Survey, which started in 2000 and is still running, employs a dedicated 2.5-metre telescope in New Mexico. So far, it has yielded over four million spectra of both stars and galaxies, out to distances of billions of lightyears.

Finally, the Dark Energy Spectroscopic Instrument (DESI) at the 4-metre Nicholas U Mayall Telescope at Kitt Peak Observatory in Arizona, which is very much complimentary to ESA's Euclid mission, is expected to complete its five-year redshift survey of 35–40 million galaxies in 2026.



▲ The Sloan Digital Sky Survey, the largest 3D map of the cosmos to date, will be eclipsed by Euclid's study of over two billion galaxies

▶ the current large-scale structure of the Universe evolved from primordial density perturbations a few hundred thousand years after the Big Bang, which have been mapped in detail by ESA's Planck mission (2009–2013).

"With Euclid," says Laureijs, "we will basically create 12 'Planck maps' for various cosmic epochs, by looking at slices of our 3D galaxy map at various redshifts, corresponding to different lookback times." Measuring how the large-scale distribution of galaxies has changed over time will tell astronomers if and how dark energy has also evolved. "It's really the first time we're doing this," says Laureijs.

What lensing reveals

Of course, to study the role of dark energy in this way, you have to take the existence and spatial distribution of dark matter into account too. That's where the razor-sharp images of the VIS instrument come in. Dark matter doesn't emit any form of radiation, but it betrays its presence by slightly distorting the shapes of background galaxies in a process known as weak gravitational lensing (see Weak lensing: a primer, on page 69).

According to Albert Einstein's general theory of relativity, light is bent by concentrations of mass, whether visible or dark. In other words: a concentration of mass will reveal itself through weak lensing. Thus, a statistical analysis of the shapes of millions of background galaxies at various cosmological distances makes it possible to reconstruct three-dimensional maps of the mass distribution in the Universe.

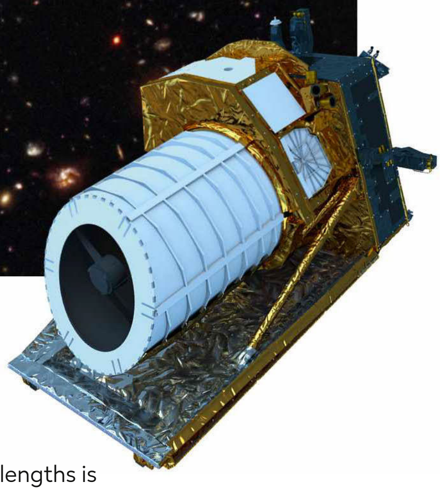

▲ The business end: the visible-wavelength VIS instrument (covered in black insulation) and near-infrared NISP (wrapped in gold insulation)

In studying weak lensing, Euclid will in fact map local deviations from the average large-scale geometry of the Universe, so it's quite appropriate that the mission has been named after Euclid of Alexandria, the 'father' of geometry, who lived in the third century BC.

In addition to mapping the distribution of dark matter and revealing the expansion history of the

SDSS, AIRBUS, NASA/STSCI/S.BECKWITH ET AL, ESA/ATG MEDIALAB

Deep impact: a patch of the southern constellation Fornax, one of the areas Euclid will scan repeatedly to build a deeper, more detailed picture



"This high-fidelity imaging of one-third of the sky at optical and near-infrared wavelengths is completely new territory"

Universe, Euclid will also measure a parameter known as gamma, which describes the growth of structures like clusters of galaxies. If this parameter doesn't match predictions from general relativity, that would support alternative theories of gravity, like Modified Newtonian Dynamics (MOND).

Digging deeper

Studying the wealth of imaging data from both of Euclid's instruments may also reveal huge numbers of brown dwarf stars, as well as low-surface-brightness galaxies. Both may be much more numerous than presently known. Many additional discoveries are expected from the three or four 'Euclid Deep Fields' (adding up to more than 50 square degrees), areas that will be repeatedly imaged by Euclid at hundreds of times more sensitivity than the main survey.

"This high-fidelity imaging of one-third of the whole sky at optical and near-infrared wavelengths is completely new territory," says Baldry. "The archived data will be used by many scientists in years to come and will have a lot of legacy impact."

No one knows for sure whether or not Euclid will really be able to figure out the true nature of dark matter and dark energy, although astronomers will certainly learn more about their spatial distribution and behaviour over time. "It also depends on what exactly you mean by 'the nature of'," says Racca. But even if these puzzling cosmic components remain enigmatic, Euclid's six-year mission will revolutionise our detailed knowledge of the Universe.

As for eye-catching photographs: dark matter can't be seen and dark energy can't be imaged, but Euclid will capture absolutely stunning pictures of the Universe, with almost the same resolution as Hubble Space Telescope images (one-tenth of an arcsecond), but with a much wider field of view. Before the end of the year, they will probably grace the pages of this very magazine. Stay tuned!

Govert Schilling is an astronomy writer and the author of *The Elephant in the Universe*

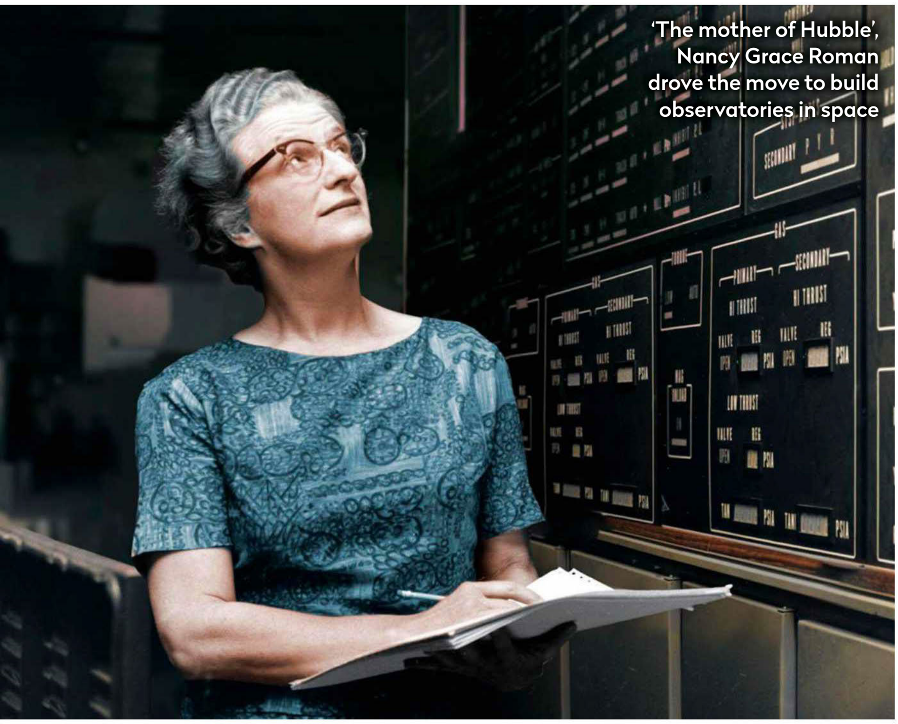
The fundamentals of astronomy for beginners

EXPLAINER

ASTRONOMERS YOU SHOULD KNOW

Nancy Grace Roman

Ezzy Pearson celebrates a scientist whose legacy can be felt across all astronomy



'The mother of Hubble', Nancy Grace Roman drove the move to build observatories in space

Nancy Grace Roman (16 May 1925 –25 December 2018) not only laid the groundwork for our understanding of how galaxies grow but also founded NASA's space astronomy programme, becoming 'the mother of Hubble'.

Roman's love of the stars was evident from an early age, and she set up an astronomy club for her friends when she was just 10. However, when she told her guidance counsellor she wanted to be a professional astronomer, she was asked, "What lady would take mathematics instead of Latin?".

Ignoring this discouragement, she went on to attain her degree from Swarthmore University before moving to the University of Chicago's Yerkes Observatory for her PhD. Here she studied the motions of stars which formed in the same cluster as the Plough, but which had drifted apart over time.

Later, Roman expanded this research to all Sun-like stars visible to the naked eye and soon noticed that where stars orbited in the Milky Way was connected to their metallicity. Metals (meaning anything heavier than helium in astronomy) are only formed inside stars, so if a star contains a lot of metal it must have been born after several generations of previous stars had already produced them. Younger, metal-rich stars tended to move in circular orbits near our Galaxy's centre, while older, metal-poor stars were further out.

This connection was the first clue towards understanding how the Milky Way grows over time, providing the foundation for modern studies of galactic evolution. Her work also developed a method of gauging stellar metallicities by comparing their brightness at blue and ultraviolet wavelengths, which is still used today.

Onwards to NASA

Despite these landmark discoveries, Yerkes Observatory refused to grant a woman a permanent position, so in 1954 Roman moved on to the Naval Research Laboratory in Washington DC to work in the emerging field of radio astronomy. Here, she mapped out the Milky Way in new wavelengths, became head of microwave spectroscopy and consulted on the Vanguard satellite programme.

With radio astronomy still in its infancy, the instrumentation was inadequate for Roman's needs, and she didn't want to retrain as an electronics engineer to build her own. So in 1959 she moved on to the National Aeronautics and Space Administration, NASA, as the head of observational astronomy, just one year after the agency had been established.

This new role effectively brought an end to her research, but with it Roman became the first woman to hold an executive office at NASA, giving her overall responsibility for the growing agency's space-based observatories.

Initially many ground-based astronomers were stubbornly opposed to using remote satellites, but Roman worked tirelessly to convince them of the benefits of observing above Earth's atmosphere. Believing the best way for the US to glean these benefits was for NASA to oversee all major space observatories, Roman was initially the sole voice in deciding which projects would get funded. Though

Ezzy Pearson is *BBC Sky at Night Magazine*'s features editor. Her book *Robots in Space* is available through History Press

NASA ARCHIVE/ALAMY STOCK PHOTO, NASA, GSFC/SVS

As well as hunting dark energy, the infrared telescope will image thousands of distant exoplanets

The Nancy Grace Roman Space Telescope

Building on her pioneering work, the new instrument will expand our understanding of the cosmos

While she may not currently be a household name, Roman will soon be much better-known, as an infrared telescope named in her honour is set to launch in 2027. The Nancy Grace Roman Space Telescope will have a 2.4m mirror – the same size as that of the Hubble Space Telescope – but its Wide Field Instrument will have a field of view 100 times that of Hubble's infrared camera.

It will use this huge view to create a 3D map of galaxies, galaxy clusters and distant supernovae to measure how matter is distributed throughout the Universe. These observations will compliment those by ESA's upcoming Euclid mission (see **page 66**) in the quest to trace dark energy, the mysterious force that appears to be accelerating the expansion of the Universe.

The telescope will even be able to map out otherwise invisible dark matter using a method called microlensing. When light from a distant galaxy passes another massive object, its path is bent slightly, becoming stretched and distorted. These distortions can then be analysed to reveal how matter is distributed throughout the cosmos.

Lensing also happens when a planet passes in front of its host star, and the telescope will monitor 100 million stars in the hopes of spotting a star's brightness fluctuating as an exoplanet passes in front. Most excitingly, this technique should be able to reveal small rocky worlds in habitable orbits, similar to our own Earth.

Roman explains the Advanced Orbiting Solar Observatory to Buzz Aldrin in 1965

Pictured in 2017 with a model of the Hubble Space Telescope, one legacy of her time at NASA

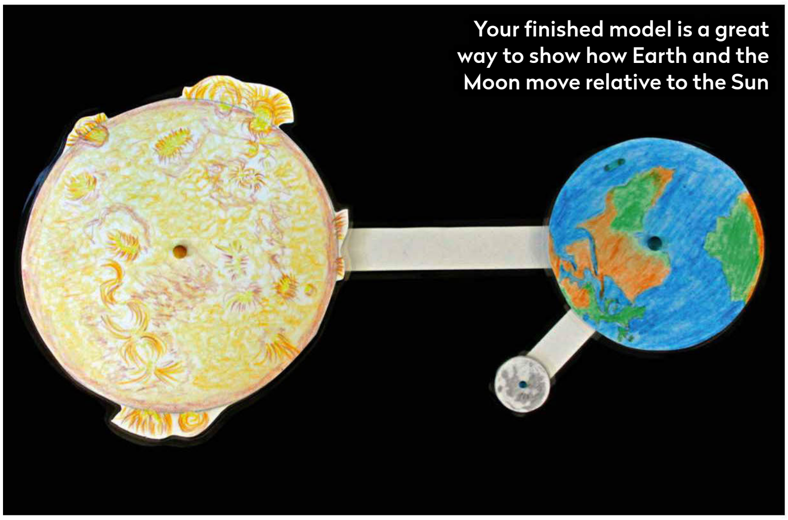
many of her colleagues advocated for NASA to build a large space telescope, she dismissed the plans as premature, instead electing to fund a series of smaller satellite observatories.

Only in 1968, after a decade of success proved NASA's capability, did Roman return to the idea of a bigger mission, though it took another three years of feasibility studies and funding before she could finally establish the Large Telescope Steering Group. It would take dozens of institutions 20 years to complete the project, but the telescope launched in 1990, renamed the Hubble Space Telescope.

Although Roman was heavily involved in overseeing the mammoth project's early years, she retired from NASA in 1979 as chief of astronomy, returning occasionally as a consultant. She continued outreach work as part of her own lifelong mission to champion the inclusion of women in astronomy. Her vision and many legacies, both scientific and cultural, continue to shape astronomy to this day.

Make a Sun, Moon and Earth model

A simple, hands-on project to teach their surface features and orbits to beginners and youngsters



Your finished model is a great way to show how Earth and the Moon move relative to the Sun

The concept of lunar and planetary orbits can be difficult for beginners to grasp. This simple flat model will help you to introduce these ideas by showing that the Moon is in orbit around Earth, but the Earth–Moon system is also orbiting the Sun. The model is easy to make using just one sheet of A4 card, some paper fasteners and a dash of artistic flare.

Although Earth and the Moon in our model are the correct sizes relative to each other, it goes without saying that the size of the Sun and the distances between the bodies are not to scale. If they were, our Sun would have a diameter of 10.9 metres, the distance between Earth and the Moon would be 2.76 metres and the distance between the Sun and Earth would be 1.2km. If the Sun and Earth were the correct sizes relative to the distance in our model, the Sun would have a diameter of approximately 2mm and the Earth a diameter of approximately 0.018mm. The surprising size of these numbers is a great teaching opportunity, conveying the fact that space is big! Models and diagrams commonly used to show our Solar System are never to scale because the relative sizes and distances are far too large.

There are several more learning outcomes from creating this project. When drawing Earth, there is much to learn about the geography of our home planet – not just the shapes of the continents, but also why some areas are very green and lush while others are brown and arid. There are many photographs of Earth as seen from space online, so choose one that shows the continent where you live.

Mary McIntyre is an astronomy educator and teacher of astrophotography

Sketch the surfaces

When drawing the lunar surface features, you are creating an astronomy sketch of a full Moon, a skill that is extremely useful as an astronomer. There is an opportunity here to talk about why the lunar maria are darker in colour and how craters and their ejecta rays form. Finally, when you draw the features of the Sun you can look online at photos from the Solar Dynamics Observatory, taken at different wavelengths that day, and choose your favourite. There is so much to learn when studying solar features photographed at different wavelengths and it shows what a dynamic place the Sun is. Drawing those solar features is more astronomy sketching practice.

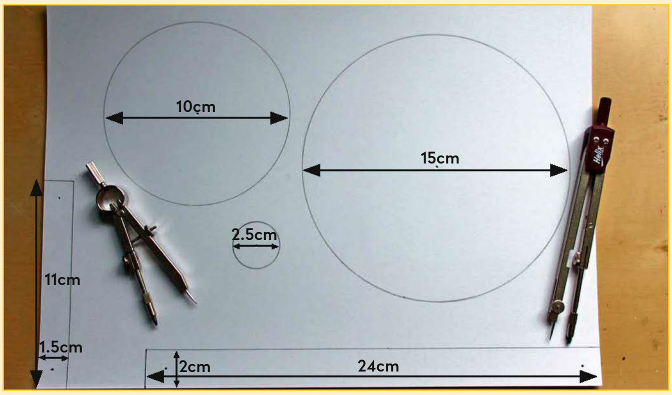
Once it's made, you can use this model to demonstrate how the Sun, Earth and Moon spin on their own axes and how the orbits of the Moon and Earth would look if we observed them from above. All three of these bodies rotate on their axes in a counterclockwise direction, and Earth's and the Moon's orbits are also counterclockwise. You can also use the model to demonstrate the position of the Sun, Earth and Moon during different lunar phases.

The lamination step is optional, but laminating the pieces will make your model more robust and easier to keep clean, so you'll be able to enjoy it for longer.

What you'll need

- ▶ 1 x white A4 card thick enough to hold its shape, but not too thick (we used 240gsm card)
- ▶ Pair of compasses for drawing 2.5cm, 10cm and 15cm circles. If you don't have compasses, just draw around circular household objects of a similar size
- ▶ Coloured pencils or felt-tip pens, and HB pencils for drawing and colouring the features on the Sun, Earth and Moon
- ▶ Paper fasteners. We used small, coloured ones but any will do
- ▶ 1 x A4 laminating sheet and a laminating machine (optional)

Step by step



Step 1

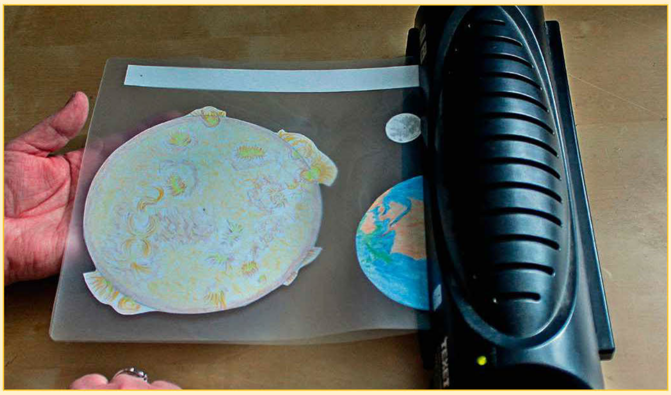
On the white card, draw two rectangles for the arms: one measuring 1.5cm x 11cm and the other 24cm x 2cm, then put a dot 1cm from each end. Use the compasses to draw three circles with diameters of 2.5cm, 10cm and 15cm.

Step 2

Using a full Moon photo for reference, sketch and blend the lunar surface features. Then find a photo of Earth from space and colour in the world's features. Finally, add the solar features using photos from the Solar Dynamics Observatory as a guide.

Step 3

Carefully cut out all of the shapes, making sure to cut around any prominences that protrude from the limb of the Sun. Using the compass point, pierce a hole through the centre of each circle and through the dots you marked on the straight pieces.



Step 4

Lay the pieces out on the laminating sheet, making sure each piece has plenty of space around it (we secured them in place with a tiny piece of double-sided tape). Carefully guide the sheet through the laminator. Let it cool before picking it up.

Step 5

Cut the pieces out again, leaving a sealed border around each piece. If you cut too close to the edges, the sheet will delaminate. The thicker your card, the wider the border will need to be. Once your pieces have cooled, pierce the holes again.

Step 6

With paper fasteners, attach the short and the long arms to the back of the Earth piece. Attach the Moon to the end of the short arm and the Sun to the end of the long arm. All the pieces should freely rotate. Your model is now ready to use.

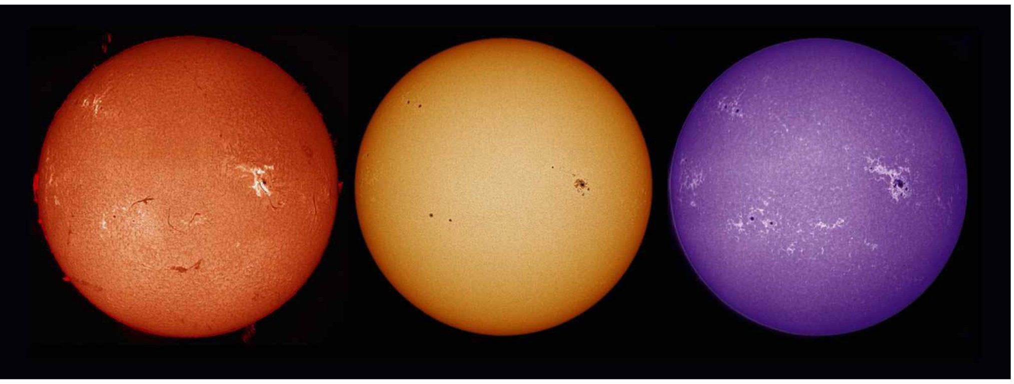
Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

CAUTION
Never observe or image the Sun with the naked eye or any unfiltered optical instrument

Catch the Sun

How to safely capture the drama now that solar activity is picking up



▲ **The same Sun photographed through three different filters (H-alpha, white-light and calcium-K) reveals markedly different views of our star**

The Sun has been showing increased activity over recent months and with its position in the sky now optimal from the UK, this is a great time to review some of the techniques required to image it. Solar imaging isn't without risk, and concentration needs to be high at all times to avoid accidents. It goes without saying that you should never look directly at the Sun nor point any instrument at it without using appropriate filters.

The two most common ways to view the Sun using a telescope are in white light or with a solar narrowband filter. Ready-made white-light filters are available or you can make your own (following instructions provided by the supplier).

Narrowband filters are more expensive and can be either built into a dedicated solar telescope or supplied to convert a night-time telescope, typically a refractor, into a speciality narrowband instrument. Common narrowband filter types offer views in hydrogen-alpha or calcium-K, the former being the most common. Other wavelengths are also available.

White-light filters show photospheric phenomena such as sunspots, sunspot groups, faculae, limb darkening, solar granulation and – very rarely – solar flares. Features in white light tend to change in form subtly over the course of a few hours or days.

H-alpha filters reveal chromospheric and inner atmosphere (corona) features including active regions, plage, spots, spicules, filaments, fibrils, dark mottles, prominences and flares.

Calcium-K filters give views similar to white light, enhanced with elements of the solar chromosphere. This can include bright prominences. Active sunspot regions are particularly clear with a calcium-K filter, as are the bright plage regions associated with them. H-alpha views are the most dynamic and can change noticeably over the course of hours and sometimes minutes. Calcium-K features exhibit changes over timescales similar to the white-light view.

Whichever filter you use, the goal is to reduce the intensity of the Sun to a level suitable for direct imaging. Once that's done, the approach is then no different to that required for, say, the Moon. Here, monochrome high-frame-rate cameras are king, their rapid capture rates helping to overcome seeing effects. In addition, the essentially monochromatic nature of narrowband filters removes the effects of atmospheric dispersion where lower altitudes spread an object's light into a spectrum of colour, effectively muddling the view. Similar refinement can be achieved in white light by using a green filter, which increases the contrast of the slightly magenta dividing lines between solar granules, the fine rice-paper-like pattern that crosses the photosphere.

Solar activity waxes and wanes over a period of around 11 years. Near solar maximum, sunspots litter the Sun's disc on a daily basis. The next solar maximum is predicted for July 2025 (plus or minus eight months), making this a great time to begin your visual record of our nearest star.

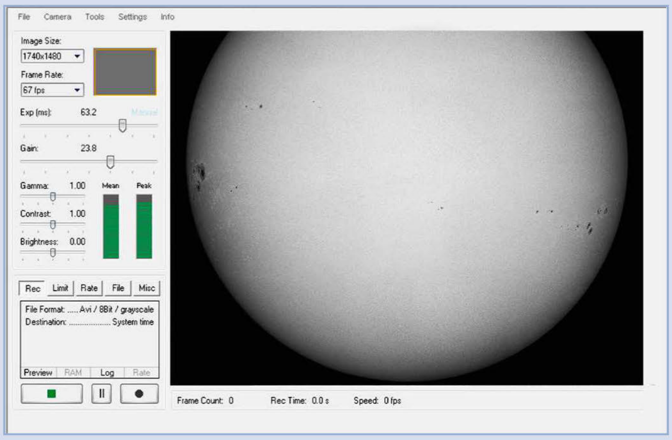
Pete Lawrence is an expert astro-imager and a presenter on *The Sky at Night*

Equipment: Equatorially-driven telescope with appropriate solar filters, high-frame-rate camera

✉ **Send your images to:**
gallery@skyatnightmagazine.com

ALL PICTURES: PETE LAWRENCE

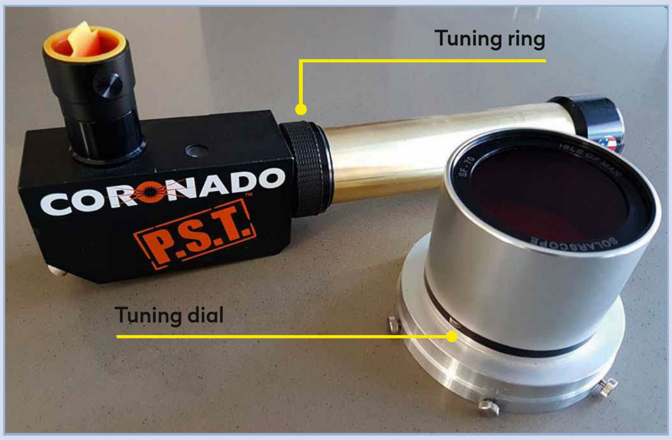
Step by step



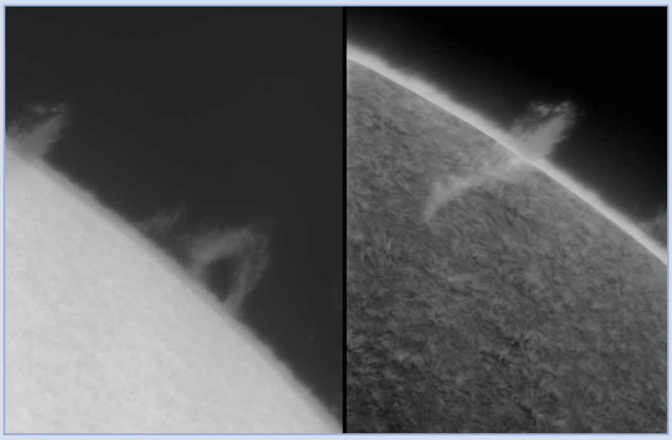
STEP 1
Before fitting a white-light filter, hold it up to the Sun and check its integrity. If it has any rips or breaks, discard it and get a new one. Make sure all finders are capped or removed before pointing the scope towards the Sun. For larger scopes with secondary obstructions, use a filtered offset aperture mask.

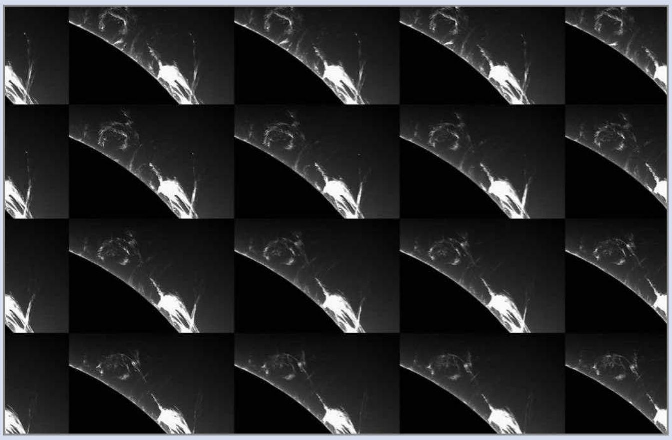
STEP 2
Adjust camera levels so the middle of the Sun appears bright, but not overexposed – around 80–90% peak level. Focus is critical. If spots are seen, use these. If the disc is blank, use the Sun's edge to achieve focus. You may or may not see the photosphere's granular texture, depending on scope size and seeing conditions.

STEP 3
Dedicated H-alpha scopes are easiest to use, requiring little more than focusing and filter tuning. H-alpha adaptor kits come in different forms. A forward-fitting etalon requires a matching blocking filter at the eyepiece end. A rear filter such as the DayStar Quark is a single unit that fits in the eyepiece holder. Always consult manufacturer's guidelines for your setup before use.



STEP 4
The H-alpha Sun shows more detail than the white-light view. With a correctly tuned filter, contrast should be good enough to show features that you can use for accurate focusing. A mono camera is highly recommended; the internal filter matrices of a colour camera greatly reduce its efficiency and image quality.





STEP 5
H-alpha features can have a wide brightness range, so aim for peak levels of 70–90%. For bright prominences, peak at 90–95%, process, then cut and paste the surface into a separate layer for processing. Inverting the surface can improve joins. Faint prominences may require surface overexposure.

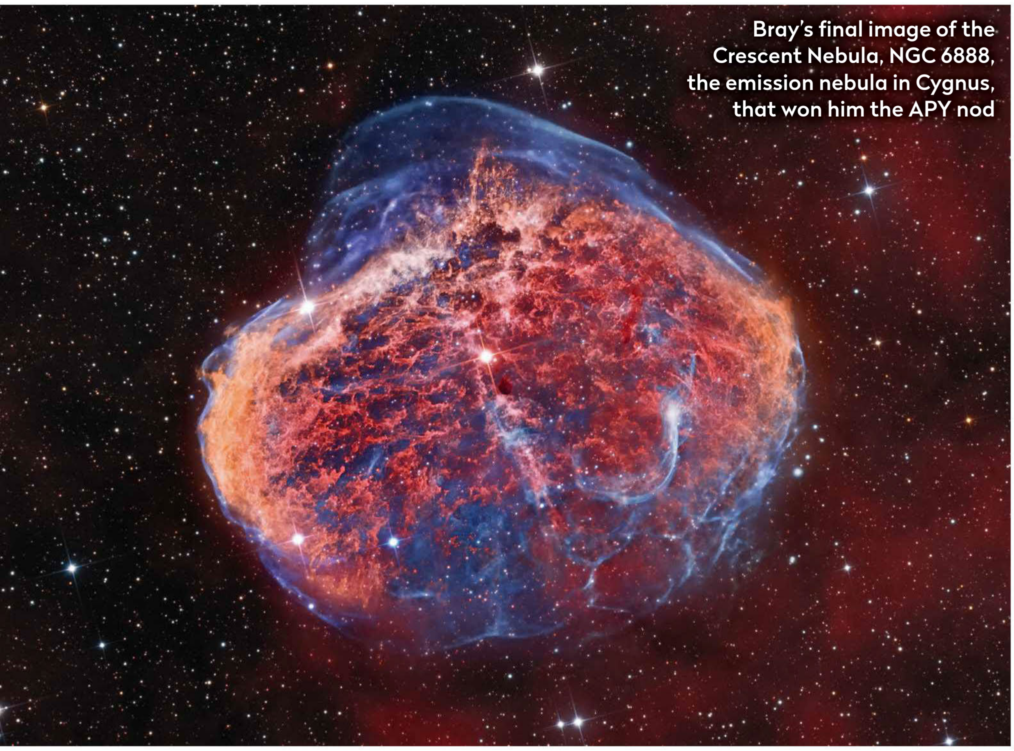
STEP 6
For active, rapidly changing solar features, you can take still images at regular intervals and combine them into an animation. Process each shot in a similar way before building the animation, otherwise flickering may occur as the sequence is run. For very active features, consider using intervals of 20–60 seconds.

ASTROPHOTOGRAPHY PROCESSING

Boosting detail in nebula photos – a case study

Combine RGB and narrowband data to give deep, rich images

Astronomy Photographer of the Year
Advice from a 2022 shortlisted entrant in the 'Stars and Nebulae' category


Bray's final image of the Crescent Nebula, NGC 6888, the emission nebula in Cygnus, that won him the APY nod

In 2022, my image of NGC 6888, the Crescent Nebula was shortlisted for the Astronomy Photographer of the Year competition. In this article I hope to give you an idea of how the image was created.

The first step with any astrophoto is to collect the data. This stage is crucial because the quality of the starting data will determine how good the finished image is; 45 hours of very high-quality data was collected for this image. Once collected, I moved onto processing, and the first step here was image calibration and integration.

These steps removed artefacts from the raw data and averaged together a large dataset to remove random noise from the final image. This was absolutely necessary because the signal in any single capture is very faint. We had to average together many images to improve it, and this had to be done for each filter used. In the case of this image, there were five different filters, shown in Figure 1.

Next, the five filtered images had to be composed to generate a colour photograph, but this process was not so straightforward thanks to the two narrowband images in hydrogen-alpha (Ha) and oxygen (OIII). These were captured with very narrow-spectrum filters, so they couldn't be reconciled easily with the more standard red, green and blue (RGB) filtered images. The five images were composed into two, which were then carefully blended.

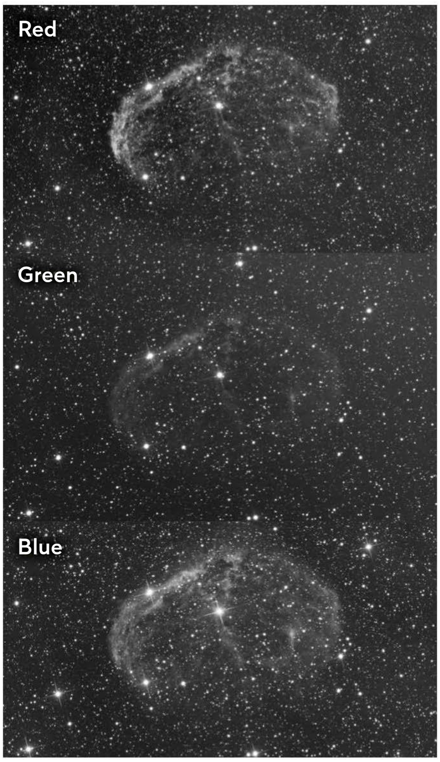
The first of these was a natural-light RGB image and there was also a 'HOO' image. Here the Ha data occupied the red channel, while the OIII data occupied green and blue. This created relatively natural tones for this object, as shown in Figure 2.

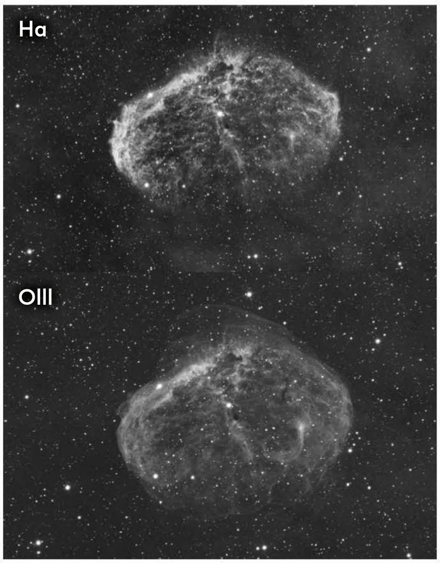
Here you can see the RGB image on the left and the HOO image on the right. While the colours of the HOO image are not strictly true, you can see they lined up relatively well with the true colours of the RGB image. This is because hydrogen-alpha emission is truly red, while OIII emission is truly teal. So, the data from one occupied red and the other occupied green and blue to form teal. In this way I was able to mimic the natural colours with narrowband filters, which gave the final image much more contrast.

Stretch the histogram

Now, while these images were colour-combined, they didn't look like this right after capture. They were 'linear images', which means the data within them was still how the camera perceived it. I had to brighten the images to reveal what was contained within, but in reality they looked like they do in Figure 3.

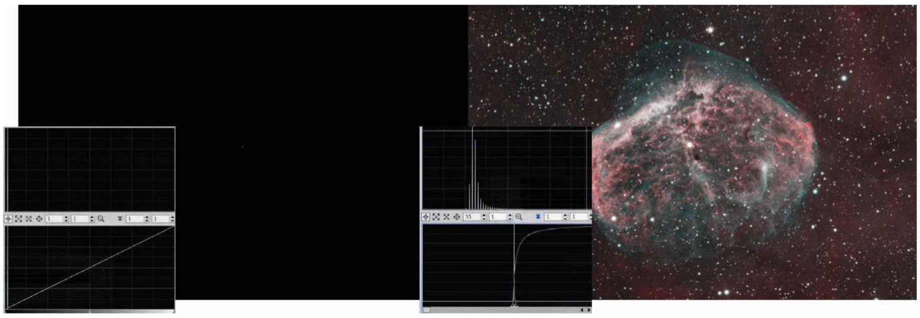
The left is the raw image and its histogram. As you can see, it is mostly





◀▲ **Figure 1: Bray began with 45 hours of data, captured using RGB (left), and Ha and OIII narrowband filters (right)**

▲ **Figure 2: the natural-light RGB images combined together (left) and the combined Ha and OIII (HOO) image (right), where Ha data occupies the red channel and OIII data occupies both the green and blue channels**



▲ **Figure 3: Comparison between the raw unprocessed image (left) – note it's normal for it to look all black – and the processed data (right) after performing a histogram stretch**

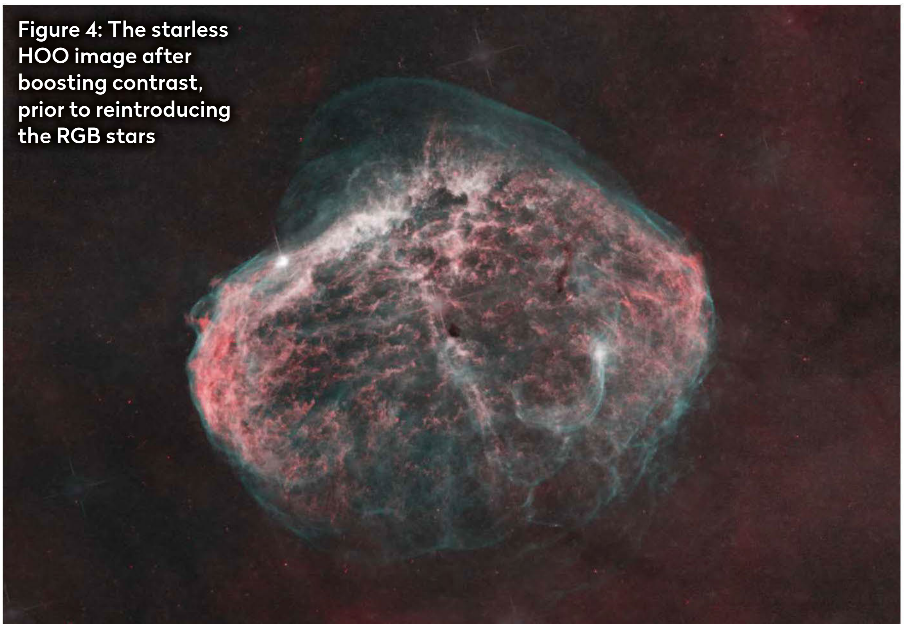


Figure 4: The starless HOO image after boosting contrast, prior to reintroducing the RGB stars

3 QUICK TIPS

1. If you skimp on image calibration, you will pay for it in post-processing.

2. Your raw images must be stretched to see the data within; it is normal if they look all black.

3. Narrowband colours are not 'true' and HOO isn't the only colour palette. You can get creative and try flipping it to OOH!

black. The histogram shows all the image details are buried within the shadows of the image. I needed to do a 'histogram stretch', which is a maths function that transforms small numbers into big ones. This took the shadows and made them into midtones, using the 'Midtones transfer function', usually configured with three sliders on the histogram in image-processing programs. By moving these sliders, I expanded and stretched the raw photo to reveal the detail.

Once this process was completed for both RGB and HOO photographs, I was ready to post-process them for aesthetics. The principal issue at this stage was combining the RGB and HOO photos together. The RGB image had desirable natural star colours, while the HOO image had high-contrast nebula details. To take the best features from each, I needed to get rid of the stars in the HOO image to make room for the RGB stars, as seen in Figure 4.

This was my favourite part of editing, because the stars obscure a lot of the detail present in the image. Without them, the nebula is portrayed in its full detail. With this stage done, I performed some colour and contrast changes to make the image more striking. I also extracted the stars from the RGB image (where the stars retained good colours) and blended them back in using the 'Screen' layer-blending mode in Photoshop. This gave me the best of both worlds: the high-contrast details and the natural star colours, all in one finished image, which you can see on the page opposite.

Bray Falls is a full-time astrophotographer specialising in sharing the process of creating images of deep-sky objects

Your best photos submitted to the magazine this month

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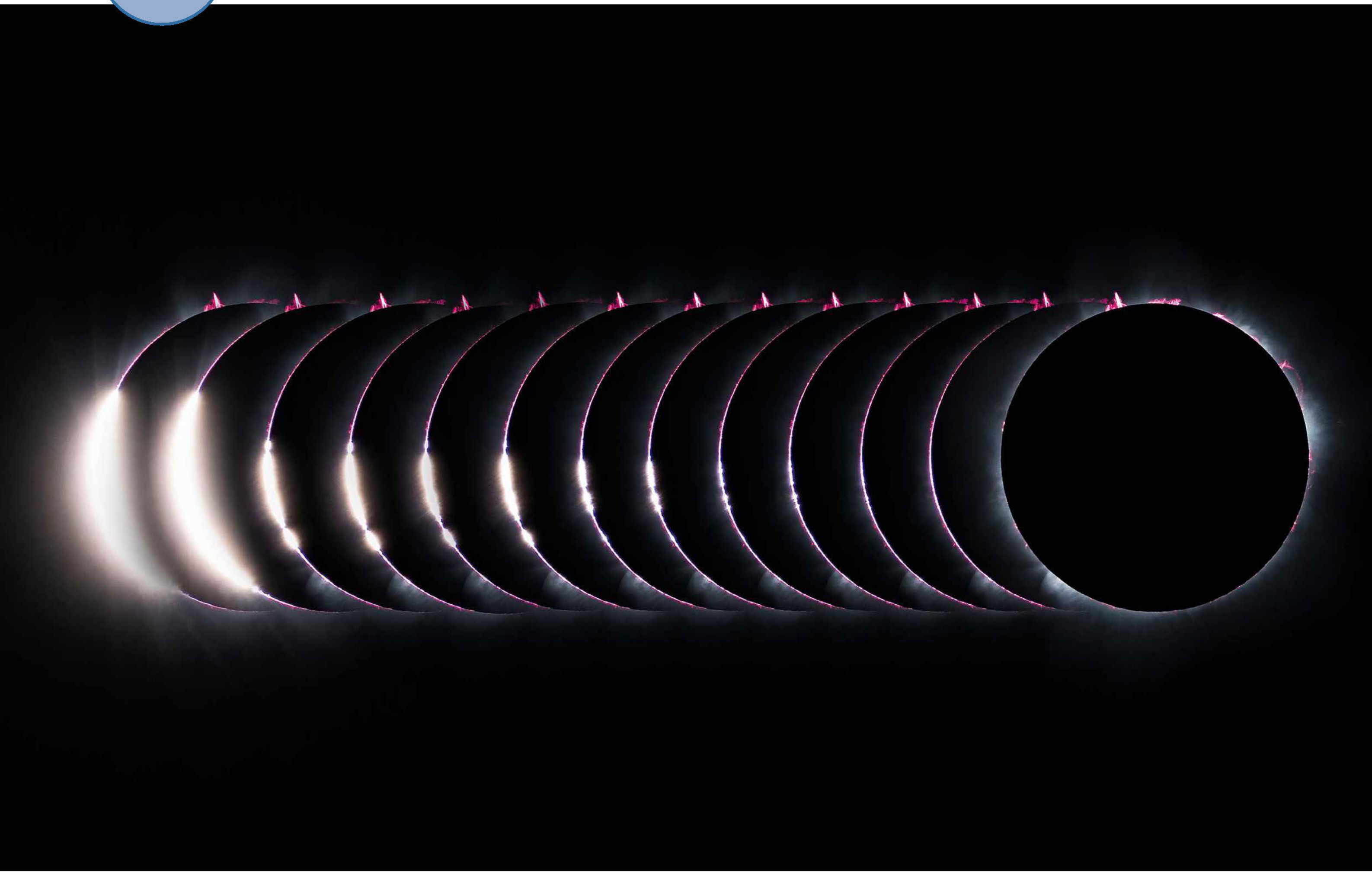
PHOTO OF THE MONTH



△ Solar eclipse

Chirag Upreti, South Lefroy Bay, Western Australia, 20 April 2023

Chirag says: "The solar eclipse achieving totality was a fantastic experience – albeit it only lasted about one minute, and that was the fastest minute of my life! I was motivated to capture the transition from the diamond ring to Baily's beads and finally the surreal black Sun. Watching it occur in real time, it almost felt like the Moon was snapping into place as it blocked out the Sun. "

Equipment: Sony a7R III mirrorless camera, Sony 200–600mm lens, Peak Design Travel Tripod
Exposure: each image ISO 320 f/9.5, 1/2,000"
Software: Photoshop

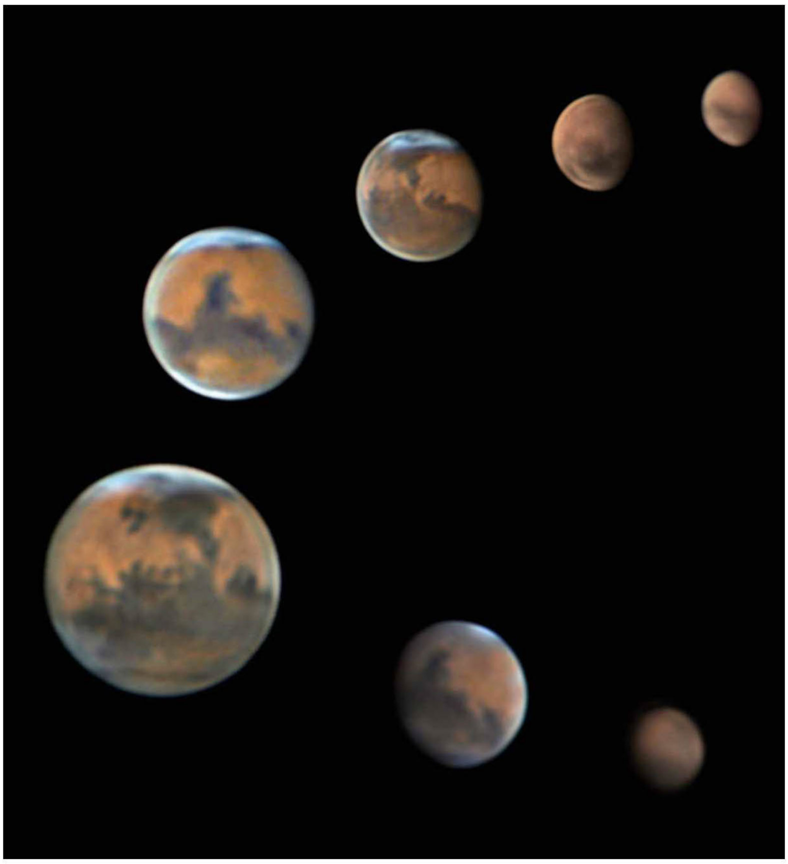
Chirag's top tips: "For solar imaging or observing, make sure you're using solar filters from reputable suppliers, or eyeglasses that are ISO 12312-2 certified. During a total eclipse, the 'diamond ring' effect is a phenomenon that occurs just before and just after totality. For images like this one, I always shoot in raw format with a focal length of 400–600mm. This gives details of the solar surface such as solar prominences and the chromosphere, and also allows me to get enough of the wispy corona. My technique is I tend to use a sunspot as my point of focus and I keep checking my focus every few minutes throughout the shoot."

△ Aurora borealis

John Cuthbert, Glencoe, Scottish Highlands, 24 April 2023

John says: "When we arrived at the cottage there was total cloud cover, so we pushed on to Loch Leven. Then on the way back a break in the cloud gave us a 10-minute window in front of the cottage, which makes a great foreground feature."

Equipment: Sony a7R II mirrorless camera, Zeiss Batis 25mm f/2 lens, Manfrotto tripod
Exposure: ISO 1600 f/2.8, 20" **Software:** Capture One



△ Mars

Ivana Peranic, Brighton, July 2022–April 2023

Ivana says: "I started imaging Mars in July 2022 and followed its approach as much as weather allowed until opposition in December. After that it became harder to catch because I'm boxed in between buildings in the city, but I made a few trips out to follow its waning phase."

Equipment: ZWO ASI662MC camera, Celestron CPC 800 XLT Schmidt-Cassegrain **Exposure:** Various **Software:** AutoStakkert!, RegiStax, GIMP

△ Moon over the Pyramids

Wael Omar, Giza, Egypt, 6 April 2023

Wael says: "I had to climb a 70-metre minaret, which wasn't easy during a 16-hour fast without food or water for Ramadan."

Equipment: Canon EOS 200D DSLR camera, 18–55mm lens; Sony A7 III mirrorless camera **Exposure:** ISO 800 f/9, 3.5"; ISO 2500 f/5.6, 0.5" **Software:** Lightroom, Photoshop

△ Milky Way

Mihail Minkov, Shiroka Poliana Lake, Bulgaria, 19–20 March 2023

Mihail says: "This shot has been in my head for months and I finally managed to capture it! I always wondered what it'd be like to see two Milky Way arches side-by-side, but that's impossible as they're visible at different times of the day. This 360° time-blended panorama, shot over a four-hour period, shows us what they would look like."

Equipment: Sony a7 III mirrorless camera, Tamron 17–28mm f/2 lens, iOptron Star Tracker Pro mount
Exposure: 20x ISO 3200 f/2.8, 80", 9x ISO 640 f/2.8, 180" (night); 9x ISO 640 f/2.8, 180" (morning)
Software: PTGui Pro, Photoshop, Adobe Camera Raw

◁ SH 2-284

Chris Morriss, Bay of Plenty, New Zealand, 23 March 2023

Chris says: "I chose this object as I wanted to capture a relatively little-known nebula that would fit well in my field of view, was at a good altitude that night, and would be suitable for me to use the Foraxx HOO narrowband colour palette for the first time."

Equipment: ZWO ASI2600MC Pro camera, Celestron 11-inch EdgeHD Schmidt-Cassegrain, 10Micron GM1000 HPS mount
Exposure: 180x 60"
Software: Astro Pixel Processor, PixInsight

The Pleiades ▷

Olly Barrett, North York Moors National Park, Yorkshire, 21 November 2022

Olly says: "Although the central area has a strong signature in visible light, the surrounding and background areas are extremely faint. The challenge was to show them without over-editing the open star cluster area."

Equipment: ZWO ASI2600MM Pro camera, William Optics RedCat 51 refractor, iOptron GEM28 mount
Exposure: RGB 90' each, 4h 30' total
Software: PixInsight, Photoshop

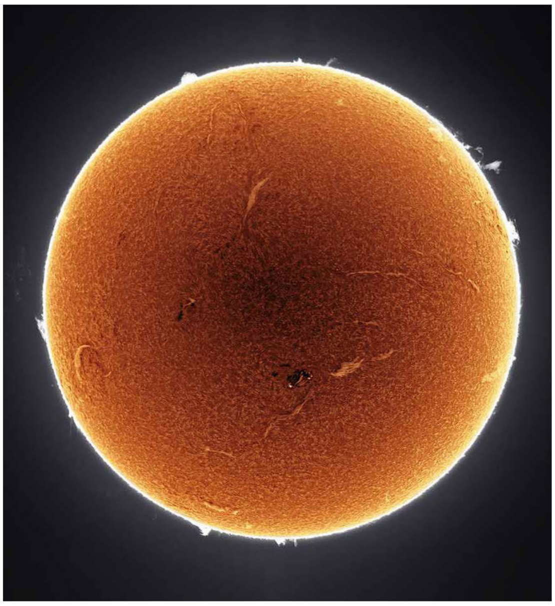
The Sun ▷

Abdulmohsen Alreesh, Kuwait City, Kuwait, 3 April 2023

Abdulmohsen says: "Fasting from food and water for Ramadan made capturing this in the sweltering heat of Kuwait a challenging choice, but it was worth it."

Equipment: ZWO ASI174MM camera, Lunt LS100MT solar telescope, Rainbow Astro RST-135 mount

Exposure: 2,000 frames at 3.5ms **Software:** ImPPG, Photoshop



▽ Vela supernova remnant

Vikas Chander, remotely via Deep Sky Chile, 1–12 April 2023

Vikas says: "Call me a widefield junkie – the wider the better! And if it's in the Southern Hemisphere, that's the icing on the cake."

Equipment: ZWO ASI6200MM Pro camera, Takahashi Epsilon E-160ED reflector, Software Bisque Paramount MX+ mount

Exposure: L 36x 300", R 24x 300", G 24x 300", B 24x 300", Ha 24x 300", OIII 24x 600" **Software:** PixInsight

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86
Smooth operator: we put Rother Valley Optics' elegant new refractor to the test

PLUS: new books on the art of NASA, *Matrix*-style simulations and diversity in space, and astro gadgets galore

HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★★ Very good
★★★★★ Good ★★★★★ Average ★★★★★ Poor/avoid

RVO Horizon 102 ED doublet refractor

A seriously smooth performer for both high-quality views and impressive images

WORDS: CHARLOTTE DANIELS

VITAL STATS

- **Price** £1,095
- **Optics** Air-spaced FPL-53 ED doublet
- **Aperture** 102mm
- **Focal length** 714mm, f/7
- **Focuser** 2-inch dual-speed rack and pinion
- **Extras** Losmandy mounting bar, Vixen-style top accessories bar, aluminium flight case
- **Weight** 5.8kg
- **Supplier** Rother Valley Optics
- **Tel** 01909 774521
- **www.**rothervalleyoptics.co.uk

The Horizon 102 ED Doublet is the latest addition to the Rother Valley Optics (RVO) family of Horizon refractors, which includes the Horizon 60, 72 and 80 doublets. It offers both the largest aperture and longest focal length of the series at 714mm, giving a focal ratio of f/7. We received the standard package (carry case and telescope with tube rings and bar), along with a suite of optional accessories to help with our test, including a finderscope, reducer/flattener and stand-alone field flattener.

Adorned with the smart-looking RVO Horizon logo, the telescope gave an excellent first impression, not least because of the unique blue, red and orange detailing on both the optical tube assembly (OTA) and matching optional 50mm guidescope. A closer inspection confirmed excellent build quality, with not a hint of plastic in sight and all parts machined with an attractive brushed metal finish. We made an early note of the Horizon 102 ED's weight of 5.8kg without accessories; unsurprisingly, given the substantial optics, this is not an OTA suitable for lightweight or star-tracker mounts. With a CCD and finderscope attached, the total setup weighed 7.5kg, which, particularly for imaging, is more suited towards mounts with a payload of at least 15kg. This member of the Horizon family is therefore likely to appeal to seasoned imagers who possess heavy mounts.

Reliably round stars

That isn't to say that setting up the Horizon 102 ED for our visual and imaging test wasn't a breeze; the substantial Losmandy bar supplied with the OTA made balancing on our pier-mounted Sky-Watcher EQ6-R quick and easy. Our first clear night with the Horizon 102 ED coincided with an 80%-illuminated Moon and so, popping a diagonal and eyepiece in, we swung over and enjoyed some lovely crater detail ▶

Ample aperture

Its 102mm aperture – relatively large for a refractor – places the Horizon 102 ED firmly in the heavyweight range, ensuring that as much light as possible hits the camera sensor and granting astrophotographers access to fainter, more delicate objects. This glass, coupled with a focal length of 714mm, also means more detailed captures of popular Messier and NGC classics. The addition of the optional, specially designed 0.8x reducer/flattener provides a wider field of view should you wish to image larger objects.

Meanwhile, the FPL-53 glass is designed to limit chromatic aberration (such as colour fringing and halos) over legacy FPL-51 glass. Rother Valley Optics bench-tests each OTA before delivery to ensure it meets the highest optical standards. A summary of this test is included with each Horizon 102 ED.

The Horizon 102 ED's aperture and focal length also make it suitable for lunar and planetary photography when coupled with a fast-frame-rate camera.

Mounting bar for finder/guidescope

The Horizon 102 ED comes ready-fitted with a suitable top-mounted Vixen bar for attaching a guidescope, along with a shoe for attaching other accessories such as a finderscope. Such equipment often requires the purchasing of compatible mounting hardware, so these are very useful extras supplied as standard.

Losmandy dovetail bar with tube rings

The supplied and fitted wide Losmandy dovetail bar measures 10cm across and 30cm long and is perfect for this large refractor, providing for a more secure fitting suited to mid- to heavyweight mounts. It also gives plenty of length to balance the telescope with accessories and imaging equipment attached.

Retractable dew shield

Protected with a smart, metal cap that's etched with the RVO Horizon logo, the 102 ED comes with a 225mm dew shield. This can be fully retracted with the tube rings attached, which helps when storing back in the box. With the shield retracted, the OTA measures 600mm long, ensuring it remains relatively portable and manoeuvrable.

Rack and pinion focuser

The robust, dual-speed focuser with 10:1 microfocus is fully rotatable, allowing us to alter camera position without losing focus. It has a 2-inch barrel yet also comes with a 1.25-inch adaptor. The tension adjuster and focus lock reduce the risk of slippage, while the annotated measurement scale is an excellent addition, allowing users to note focus positions.

KIT TO ADD

1. RVO Horizon 102 0.8x reducer/field flattener

2. RVO Horizon 50mm finder/ guidescope

3. RVO heater bands with integrated controller

▶ despite the glare. A star test on a dark patch of sky confirmed that, even without the field flattener attached, we could enjoy round stars across the field of view with minimal colour distortion. Indeed, the long focal length of 714mm lends this scope to planetary imaging, although sadly at the time of the review the ideal planets of Jupiter and Saturn were not available to image.

We found the quality of the focuser to be seriously impressive – placing the Horizon 102 ED well in front of the average OTA in its price bracket. Not only were the large focus knobs easy to locate in low light, but the action was incredibly smooth and we experienced absolutely no play in the microfocus. This allowed us to achieve pinpoint stars swiftly and easily, as the fine-tuning proved accurate. We could already appreciate the large doublet as a visual refractor, but were keen to put it through its imaging paces.

A week later, we had clear skies and opted to try the flattener coupled with our CCD camera. Attaching it was easy, as it is designed specifically for the OTA. The required 55mm back focus was easily obtained and confirmed by a beautifully flat, consistent field of view. Homing in on the Jellyfish Nebula, IC 443, we took 60 minutes of hydrogen-alpha and 45 minutes of OIII frames. Despite damp nights, the front element remained clear even without a dew strap attached. We also noted that the focus held securely in place while switching filters. Later, post-processing in Photoshop confirmed round stars and minimal distortions. A few nights later, we took advantage of another clear night to image the Monkey Head Nebula, NGC 2174, grabbing the same time again on each narrowband filter.

To sum up, the Horizon 102 ED proved an easy-to-use, robust refractor, with the rotation adjuster allowing us to perfectly align our image without altering our focus, which – thanks to the Horizon 102 ED's excellent focuser – was already perfect.

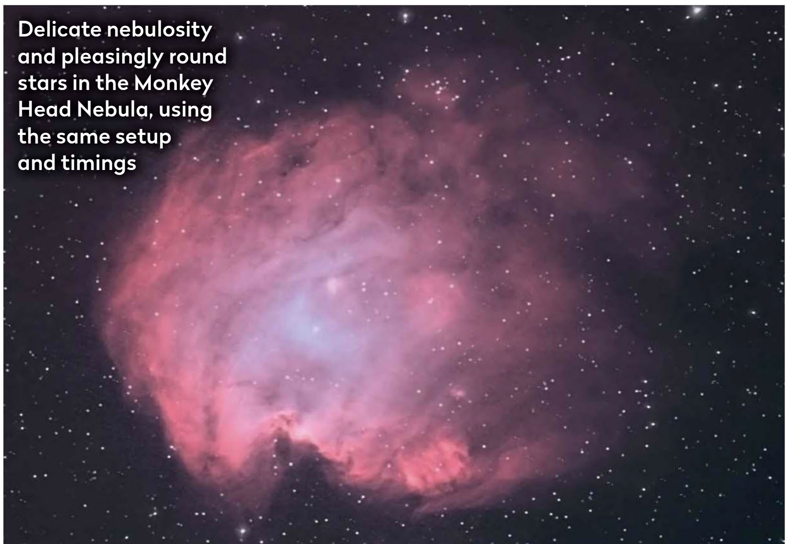
VERDICT

Build & design	★★★★☆
Ease of use	★★★★☆
Features	★★★★☆
Imaging quality	★★★★☆
Optics	★★★★☆
OVERALL	★★★★☆

Flight case with carry handle

The aluminium carry case is large enough to house the Horizon 102 ED with tube rings attached and is exceptionally well padded. There is also space to store other accessories including a finder/guidescope and a reducer or flattener, ensuring these can be kept with the OTA at all times.

The 102mm aperture delivered fine, faint detail in the Jellyfish Nebula. Paired with a Starlight Xpress H694, 2' exposures, Hα 60' and OIII 30' total



Delicate nebulosity and pleasingly round stars in the Monkey Head Nebula, using the same setup and timings

Altair Astro Hypercam 533M mono camera

Making the move to mono? This superior sub-£1,000 camera could tempt you

WORDS: TIM JARDINE

VITAL STATS

- **Price** £999
- **Sensor** Sony IMX533 BSI
- **Resolution** 9MP, 3,000 x 3,000 pixels
- **Exposure range** 0.1ms–3,600 seconds
- **Connectivity** USB 3.0 and USB 2.0 hub, 12V DC power port
- **Size** 107mm x 85mm
- **Weight** 630g
- **Extras** Carry case, 12V DC power supply, software
- **Supplier** Altair Astro
- **Email** info@altairastro.com
- **www.** altairastro.com

The Hypercam 533M is an interesting addition to the Altair Astro family of astronomy cameras, with a medium-sized sensor that allows for a cooled, high-performance unit in an affordable price range. The model we received for review was the mono version, a colour model also being available, but we matched the mono camera to our filter wheel to use our colour and narrowband filters. We used 2-inch filters, but 1.25-inch filters could also be suitable without causing vignetting, depending on the spacing and telescope involved. It would be prudent to take advice from your dealer when considering filter choices.

Nicely machined and finished, the build quality of the 107mm x 85mm camera is excellent. It feels surprisingly heavy in the hand, the unit weighing in at 630g. The thread on the front is a standard M42 x 0.75mm and can be used with the supplied nosepiece or, as we did, attached directly to our filter wheel, allowing for the 17.5mm spacing between the front flange of the camera and the imaging sensor.

Right from the start, our experience with this camera was very positive. After downloading the driver package and the latest version of the AltairCapture app, we powered up the camera and plugged it into our laptop with the included 1.5-metre USB 3.0 cable. After selecting the 533M as our camera, we configured the thermo-electric cooling to our desired target of –5°C, then set the resolution to 14-bit and we were good to go; live images started rolling in. On our system we achieved frame rates of 13.2 frames per second (fps), which rose to 25.5fps with a 'Region of interest' area set at 25 per cent of the full sensor size.

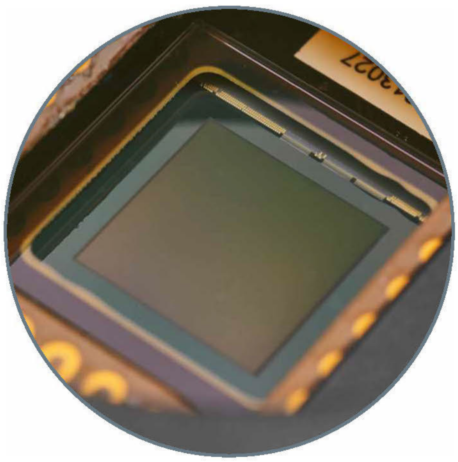
Moon movies

While the 533M is perhaps not ideal as a planetary or lunar camera with those frame rates, we did try recording a couple of AVI files of the Moon in full resolution. A 90-second video used over 10GB of storage, but the result was very pleasing, with good ▶

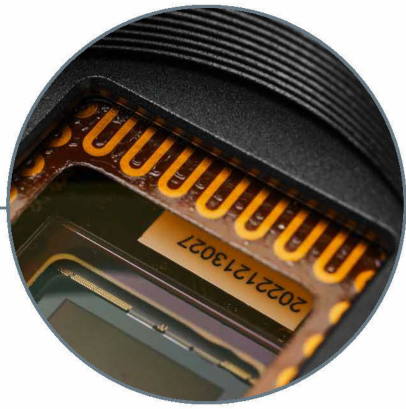
Sony IMX533 CMOS sensor

While many astro cameras have rectangular sensors, the Hypercam 533M uses a Sony IMX533 CMOS sensor with a 3,000 x 3,000-pixel array, making a square image-acquisition area. When you think about it, telescope optics produce a round image, and until someone makes a round sensor, a square makes the best use of the available image area. We found the square format was especially effective on targets like globular clusters and that framing other deep-sky objects required a little less nudging the position and rotation of the camera than usual to get the best composition.

The back-illuminated sensor has 3.76-micron square pixels, yielding 14-bit, 9MP images, although these pixels can be combined through true hardware binning to act as larger, even more sensitive pixels; on some telescopes this would allow a sensible image scale. The sensor is 16mm across diagonally, has a quoted quantum efficiency (Qe) of >80% and can acquire images of between 0.1 milliseconds and one hour in duration.



SCALE



Heated optical window

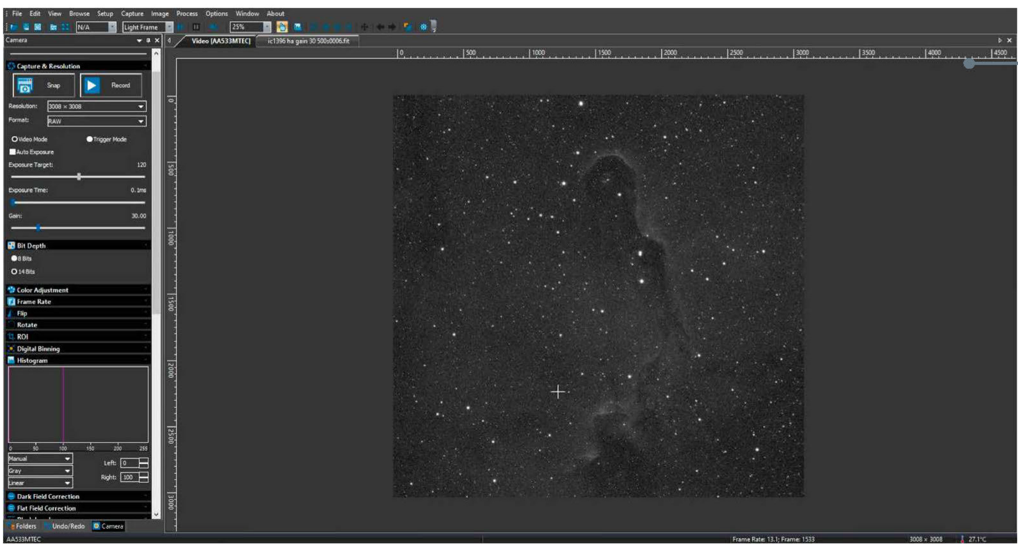
The Hypercam 533M carries a two-year 'frost-free' guarantee for the sensor, addressing the common issue of TEC cameras attracting dew on the optical window. There is also a software-controlled heating element around the outside of the anti-reflection window which can be turned on if dew becomes a problem.

USB 3.0 with USB 2.0 hub

The camera must be operated via a high-quality USB 3.0 lead no more than two metres in length. On the rear of the camera body there are two USB 2.0 sockets which allow for low-bandwidth items like an auto-focuser or filter wheel to be controlled via short leads.

Two-stage cooling

To reduce noise, the imaging sensor can be cooled up to 40°C below ambient thanks to its software-controlled cooling ability, a large heat sink and powerful, but quiet, fan. We used –5°C as a setting and the camera quickly reached and maintained this temperature throughout our long imaging sessions.



Software

A one-year licence for SharpCap Pro is provided free of charge, along with Altair Astro's own software called AltairCapture. This simple app provides full camera control, allows capture of both single FIT images and AVI files, and operates the cooling, window heating and gain settings of the Hypercam.

FIRST LIGHT

KIT TO ADD

1. Altair 3nm narrowband SHO filter set

2. Altair 2-inch magnetic filter holder with T2 thread

3. Altair 70mm F5 quad astrograph

▶ contrast and no blowing out of the bright areas.

Our real goal though, and a purpose it seems ideal for, was to photograph some galaxies, globular clusters and a couple of narrowband targets that could be captured despite the Moon. With the M3 cluster presenting itself nicely, we started on that, using the lowest gain setting, taking five-minute exposures through our RGB filters over a couple of nights. It immediately became obvious that the 533M gives very clean, low-noise images. In fact, it felt just like imaging with an old-style CCD camera in that respect.

Unlike CCD sensors though, the sensitivity performance of the CMOS sensor in the Hypercam can be increased with the gain setting, which opened up the opportunity for us to get some images of the low-lying Thor's Helmet, NGC 2359, with our narrowband filters, again using short five-minute exposures. The result was a little soft due to the low position and atmospheric conditions, but the camera gathered reasonable data through our hydrogen-alpha and OIII filters, further enhancing our favourable impression of the 533M.

It is worth mentioning that for these images we didn't take any calibration files, as we found the Hypercam presented such clean images that we deemed them unnecessary for our purposes. When observatory time is at a premium, the ability to use it to take more photographs of the actual target is always a bonus. There is no amp glow that sometimes accompanies CMOS sensors, which is another big plus point for this camera. The combination of all these positive points really makes it a most enjoyable instrument to use.

At the time of writing, the price of the Hypercam 533M is under £1,000. For a capable, easy-to-use astro camera that gives such rewarding results, it is well worth considering as an investment into the world of monochrome imaging.

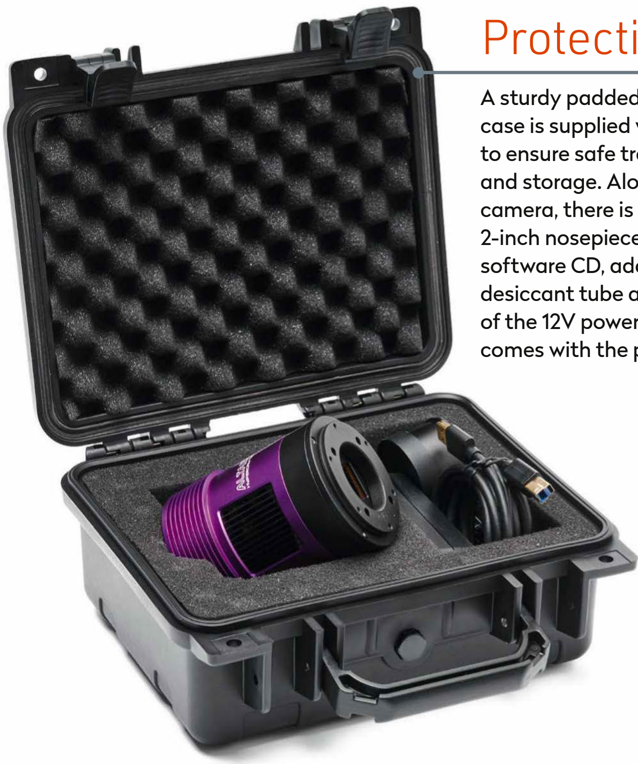
VERDICT

Build & design	★★★★★
Connectivity	★★★★☆
Ease of use	★★★★★
Features	★★★★★
Imaging quality	★★★★★
OVERALL	★★★★★

▲ This shot of the Moon, stacked from a 90-second video, got things off to an impressive start

▲ The 533M came into its own with a defined, low-noise M3 globular cluster. 5' exposures, 7 hours 45 minutes total

▲ Thor's Helmet was slightly marred by poor seeing; 5' exposures, 2 hours 45 minutes in total. All images were taken using a Sky-Watcher Esprit 150ED



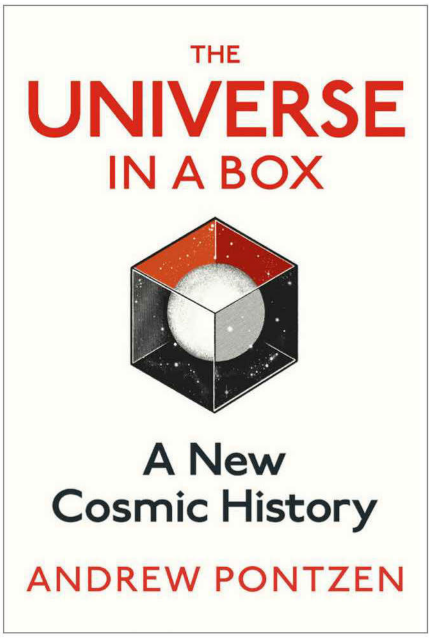
Protective case

A sturdy padded ABS-style carry case is supplied with the camera to ensure safe transportation and storage. Along with the camera, there is room for a 2-inch nosepiece and cap, software CD, additional desiccant tube and the body of the 12V power supply that comes with the package.

@THESHED/PHOTOSTUDIO, TIM JARDINE X 3

New astronomy and space titles reviewed

BOOKS



The Universe in a Box

Andrew Pontzen
Jonathan Cape
£22 ● HB

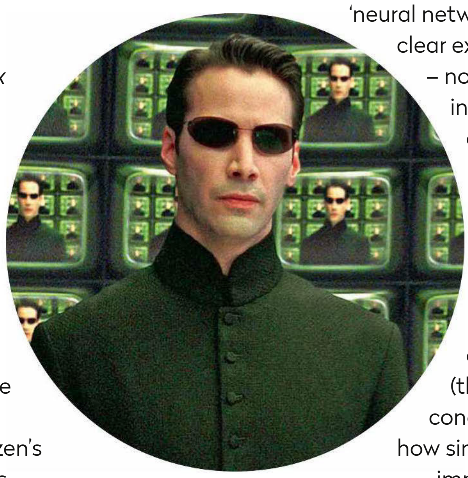
The Universe in a Box begins, rather innocuously, reminiscing about computer games from the 1980s before moving on to discuss the weather. But these familiar concepts are merely setting the tone for the rest of author Andrew Pontzen's exploration of what is now an incredibly common way to explore the Universe: using simulations. It's one thing this book does brilliantly, keeping complex topics grounded – what, after all, is more familiar than a weather forecast?

Most of the book's first half asks how the principles used when predicting the weather can be applied to exploring the Universe at large. If the idea of computer coding feels technical, you need not worry – this book is about the scientific principles involved and the practicalities of their implementation. If you're looking for details of RAM, threading and supercomputers, you won't find it here. This is for the best, since such discussions would likely date it scarily quickly.

Once it's done with simulations following the laws of physics we all know and love, *The Universe in a Box* delves into more conceptually challenging stuff. There are very accessible explanations of things like dark matter and dark energy, involving bath toys and Rudyard Kipling's *Just So Stories*. There's a nice dive into Bayesian logic, one of a number of times we see how these topics are relevant to the author's own research. And tips on how to beat a computer at tennis...

Of course, you don't have to cast more than a cursory eye on the news to have heard about the benefits – and risks – of artificial intelligence. If you've never really understood what 'machine learning' and 'neural networks' are, there are clear explanations here – not particularly in-depth, but a concise overview of the technologies.

The final chapter of the book gets philosophical and asks if we could all be living in a computer simulation (think *The Matrix*). A concluding discussion of how simulations have impacted the author's own life and career feels very personal, heart-warming and even touching – and I don't think that's just the 90s nostalgia talking! ★★★★★



From *The Matrix* to dark matter, Pontzen explores cosmic simulations past, present and future

PICTORIAL PRESS LTD/ALAMY STOCK PHOTO

***Chris North** is Head of Public Engagement at Cardiff University School of Physics and Astronomy*

Interview with the author
Andrew Pontzen

How long have astronomers been using simulations?

If we mean mimicking the evolution of the cosmos inside a digital computer, then the 1970s. But the precedents extend far further back. In the 1940s, one eccentric astronomer, Erik Holmberg, recreated colliding galaxies using dozens of light bulbs moving about inside a darkened laboratory. Ada Lovelace wrote about the possibility of simulations in the 19th century. And clockwork mechanisms to predict the orbits of planets date back to antiquity.

What big discoveries hinged on simulations?

The fact that dark matter has to be made of some substance unknown to humanity. Simulations in the 1980s showed that anything already known would be unable to sculpt the cosmic web of galaxies that we observe. Dark energy, gravitational waves from colliding black holes, even the Higgs boson – all these discoveries hinge on simulations of one type or another.

If we uncover the dark Universe, will simulations have played a big role?

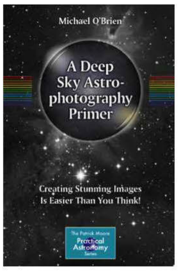
If we find dark matter tomorrow, it'll be because simulations suggested what kinds of particle to look for. Finding nothing in the next few years would also be exciting: we'd then need to look back at the sky for further guidance. Dozens of groups across the world are building simulations with new flavours of dark matter and dark energy, ready to compare with what's in the real Universe as seen through astonishing new telescopes like the Vera Rubin Observatory.

***Andrew Pontzen** is a professor of cosmology at University College London*

A Deep Sky Astrophotography Primer

ASTRO IMAGING

Michael O'Brien
Springer
£27.99 ● PB



If you've ever sighed, "I wish I knew more about (insert astrophotography subject/piece of equipment/process here)," the answers to all your questions are likely to be here!

This is a neutron star of a book, packed with so much information that some potential buyers leafing through it might be daunted by its contents, but it's written in a welcoming, personal style by an author with a gift for effectively communicating a lot of information and simplifying complicated processes.

After a short introduction, the reader is taken on a step-by-step journey through astro imaging. First, a brief overview of deep-sky imaging equipment gently introduces the kit astrophotographers use these days, followed by a discussion of the problem of light pollution and how to reduce its effects.

Sections then become more detailed, with comprehensive guides to using some of today's most popular kit, how to set up and control a telescope-plus-camera using a computer, and how to process the images using the latest software.

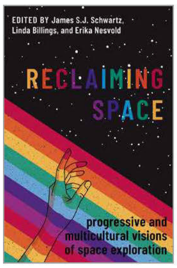
'Your First Imaging Session' is perhaps the book's most successful section. It's like having an expert imager standing beside you in the dark as you look at all your kit and wonder what you are supposed to do with it.

We've all seen telescopes groaning under the weight of CCD cameras and autoguiders, connected by so many leads it looks like a plate of spaghetti. If you've ever been bamboozled by similar sights, this book is invaluable. ★★★★★

***Stuart Atkinson** is an astronomy writer and astrophotographer*

Reclaiming Space

Edited by James SJ Schwartz, Linda Billings, Erika Nesvold
Oxford University Press
£32.99 ● HB



As the world's richest men funnel billions into spaceflight vanity projects, the future of space looks increasingly dystopian for those left on Earth below. *Reclaiming Space*, a book of essays, brings hope to visions of a space for all.

The book, subtitled *Progressive and Multicultural Visions of Space Exploration*, gives a platform to underrepresented perspectives, challenging our view of what space exploration is, and what it will look like in the future. The biographies of the contributors reveal a fascinating variety of fields, including xenolinguistics, space law and environmental philosophy.

The collection is an informative, powerful and often moving read. Views challenge each other and us, the reader, but the core themes weave them into a cohesive narrative.

Two essays in particular stand out: Mukesh Chiman Bhatt details mythologies, cultures and traditions sidelined in dominant narratives of spaceflight; while Ingrid LaFleur explores how Afrofuturism provides a reimagining of a peaceful, liberated future in space.

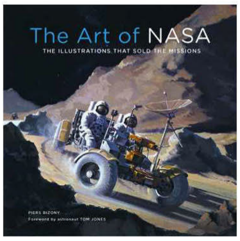
The difficulty is that in trying to host all underrepresented perspectives of space, the book simply does not have the opportunity to do them all justice. They are views often bound to the space of 'the other': a fault not with the book, but with the field itself.

But we look out on thousands of books that centre the normative narrative – that of the white, western, wealthy man. Does space need to be reclaimed? This book, and the works of its contributors, are intended to be a step towards a space for all. In the words of Ingrid Lafleur: "By imagining a new destiny, we are able to create a more balanced, peaceful, pleasurable, loving present." ★★★★★

***Katie Sawers** is a science writer*

The Art of NASA

Piers Bizony
Motorbooks International
£80 ● HB



Flicking through *The Art of NASA* conjures long-dormant memories of the kind of imagery that inspired and excited me as a child of the early 1980s: jaw-dropping planetary vistas, wheeling space colonies and sleek starships. Growing up after Apollo's halcyon days and with Shuttles and space stations a tantalising mirage on the horizon, the futuristic optimism of this sort of artwork exerted a captivatingly magnetic pull.

Much of it, to be sure, was unalloyed fantasy. Space suits were clunky and metallic, while space skies were not velvet-black and starless, as they ought to be, but carried those dramatic sweeping brushstrokes of deep blue, indigo and white. It was fantasy tinged with the merest whiff of possibility.

Science journalist and space historian Piers Bizony seamlessly weaves his artistic selections into an inspiring book of images that will whet many an appetite of grown-up-schoolkid adventurism. We see pieces rooted in real programmes, from the Saturn V to the Space Shuttle, Mercury to Apollo, and Skylab to Viking. He shares as-yet-unrealised concepts for what lies beyond our reach and must await future explorers.

What is particularly intriguing is an awareness that artistic representations of space change like the humans who paint them. As Bizony's beautiful book progresses, there is a definite shift from yesteryear's stylised imagery, tinged with Cold War fear and paranoia, to the realism and clean lines of today, inspired by space photography and a resurgent sense of optimism. It reminds us as never before that it is the future, not the past, that offers the brightest of possibilities.

This expanded and boxed collector's edition includes new material, a paper model of the Lunar Module, a poster and a collection of postcards.
★★★★☆

***Ben Evans** is the author of several books on human spaceflight*

Ezzy Pearson rounds up the latest astronomical accessories

GEAR

1 Baader 1.25-inch UHC filter

Price £71.99 • **Supplier** Harrison Telescopes
www.harrisontelescopes.co.uk

Increase contrast and cut out light pollution when viewing emission nebulae with this filter. It cuts out the most common light-pollution lines while allowing through 97 per cent of other light.

2 Redshift 9

Price €129 • **Supplier** Redshift Sky
www.redshiftsky.com/redshift-9

Plan your observing session using this extensive software suite. Includes planetarium software, an observational planner and the ability to control your telescope. This latest version has an even larger database of objects and an easier-to-use interface.

3 Retro 51 Escape fountain pen

Price £65 • **Supplier** Pen Heaven
www.penheaven.co.uk

Inspired by the Advanced Crew Escape Suit worn by NASA astronauts during launch, this fountain pen's bright orange barrel is decorated with flight patches and logos. It comes in a gift tube, with two black ink cartridges and a reusable converter.

4 Vernonscope 20mm 1.25-inch parfocal Brandon ocular

Price £279 • **Supplier** The Widescreen Centr
www.widescreen-centre.co.uk

ADVANCED Designed to reduce light scatter, give excellent contrast and maintain very dark backgrounds, this 20mm eyepiece works well in binoviewers or used individually. Choose between rubber eye cups or a flat-top design.

5 Explore Scientific adapter hybrid finder base

Price £21.50 • **Supplier** Telescope House
www.telescopehouse.com

Giant binoculars can give spectacular views, but can be difficult to navigate the sky with. This attaches to the handle, allowing you to use standard LED or optical finders to place your desired object in view.

6 UltrAspire Lumen 200 waist light

Price £50.96 • **Supplier** Alpine Trek
www.alpinetrek.co.uk

This novel torch is mounted on a waistband and illuminates the path ahead at a shallow angle, giving more shadows to identify potential obstacles. It has a red-light setting to help preserve your night vision.

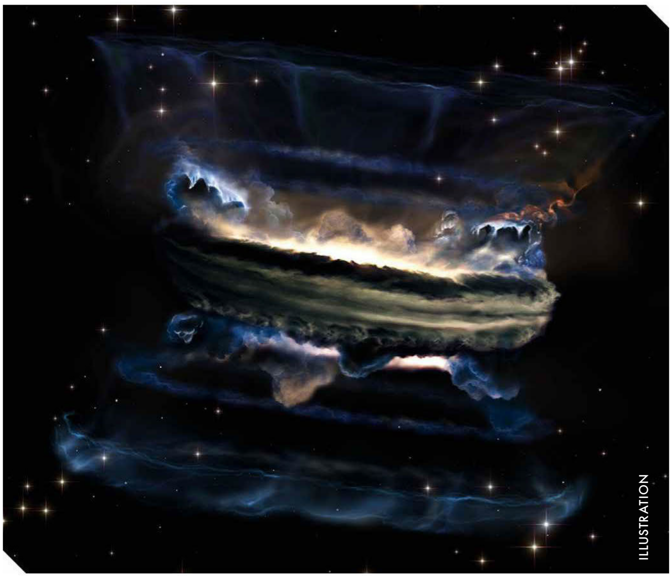
Anita Chandran interviews Dr Jonathon Pierce

Q&A WITH A GALAXY RESEARCHER

Quasars are hungry monsters at the heart of galaxies, but the origins of these powerful objects have long been a mystery

What are quasars?

We think there are supermassive black holes at the centre of every massive galaxy in the Universe. These black holes are accreting material from their near surroundings, usually gas or dust. In some cases, the powerful gravitational forces involved serve to heat up this material, resulting in intense radiation being emitted. We call these extreme objects active galactic nuclei, and quasars are the brightest and most powerful examples of them.



ILLUSTRATION

▲ Fast and furious: shortlived, ultra-powerful and super-bright quasars give us clues about how the earliest galaxies formed

What makes them such mysterious objects?

Supermassive black holes are roughly the size of a solar system. This is very small relative to a full galaxy, which could contain hundreds of millions to trillions of stars. There's lots of gas in galaxies, but the mystery lies in how this can get down to the central black hole regions to provide fuel for a quasar. One of the leading ideas is that when galaxies collide, the net effect is to throw a large amount of material towards the galactic centres, an attractive means of getting fuel to the black hole.

How do astronomers study quasars?

Quasars and active galactic nuclei can emit across the full electromagnetic spectrum, from X-rays or gamma rays all the way to radio waves, so there are many ways to study them. We have amazing telescopes operating at different wavelengths. There are two main approaches: you can look at triggering – what sets off or ignites a quasar – or you can look at the effects caused by feedback, where the energy output from the quasar impacts gas and dust within the galaxy.

What approach did your team use?

We focused on triggering, and particularly on galaxy mergers. We imaged a large sample of quasar-hosting galaxies with enough sensitivity to pick up on faint, distorted structures that indicate whether a galaxy is or has been going through a merger. We also looked at a group of non-quasar galaxies imaged in the same way; these galaxies otherwise had very similar physical properties. When we looked at the two groups, we saw that the quasar group showed signatures of mergers around three times more often than the non-quasar group. This provides strong evidence that mergers are important for triggering quasars.

What are some other theories of quasar formation?

The merging galaxy theory is the most popular, but the problem has been finding evidence. Even within our sample, not every quasar galaxy had signs of mergers, so there's got to be something else that can cause quasar activity. One theory is that gravitational structures within spiral galaxies (spiral arms or bars, for example) could channel gas towards the centre. There is also the idea that in the early Universe, at larger distances away from us, there may have been giant gas clouds within galaxies that could have collided and thrown material towards galaxy cores.

What do quasars tell us about the Universe?

Quasars are the most powerful objects in the Universe, so they're extremely interesting. The sheer amount of energy output by quasars can greatly disturb the gas in a galaxy and so its ability to form new stars. We want to understand what happens throughout a galactic life cycle, and this effect means that quasars could influence their evolution. Quasars can also be detected at large distances because they can emit light at a comparable level to a whole galaxy. Instruments like the James Webb Space Telescope can pick up on them, pushing the boundaries of how far back we can see and allowing us to learn more about the early Universe.


NIMA ABKENAR

Jonathon Pierce is a postdoctoral research fellow at the University of Hertfordshire, specialising in galactic mergers, active galactic nuclei and radio astronomy

What's next for your investigation?

We want to confirm that if we used a sample selected in, for example, the X-ray or infrared, our results still hold. It's a question of verifying that mergers are important for igniting all quasars, regardless of how they're selected.

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THE SOUTHERN HEMISPHERE

With Glenn Dawes

Watch as Venus and Mars dance over to Regulus, then visit two half-horses and run with the Wolf

When to use this chart

1 July at 00:00 AEST (14:00 UT)
15 July at 23:00 AEST (13:00 UT)
31 July at 22:00 AEST (12:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

JULY HIGHLIGHTS

Early in the month, Venus and Mars travel together towards Regulus (Alpha (α) Leonis) in the northwestern twilight. Mars has its closest approach on 10th, 0.7° from Regulus, with both a similar brightness. The planets separate as Venus heads towards conjunction, to be passed by Mercury as it returns to the evening sky. This 'speedy messenger' follows Mars's path, passing within 0.5° of Regulus on the 29th. Mercury will be brighter than the star, with Venus easily outshining them both.

STARS AND CONSTELLATIONS

Of the many mythical creature constellations, two are centaurs: Centaurus and Sagittarius, displayed high in winter evening skies. Located in the southern Milky Way, these half-horse, half-humans are not really recognisable. Only hints remain, like Alpha Centauri – Rigel Kentaurus, the 'foot of the Centaur', indicating the creature is standing over the Southern Cross. Even the famous Teapot asterism mainly marks Sagitarrius's bow and arrow, not the beast itself.

THE PLANETS

Venus continues to dominate the western twilight sky, with Mars nearby. Mercury reappears in the evening, reaching a fair altitude by mid-July. Saturn is now rising around 21:00 mid-month, followed by Neptune two hours later. Both will transit in the morning hours. Turning to the morning, Jupiter arrives in the early hours (rising at 02:00 mid-month), followed by Uranus an hour later. These are best observed in the predawn, allowing them time to reach a reasonable altitude.

DEEP-SKY OBJECTS

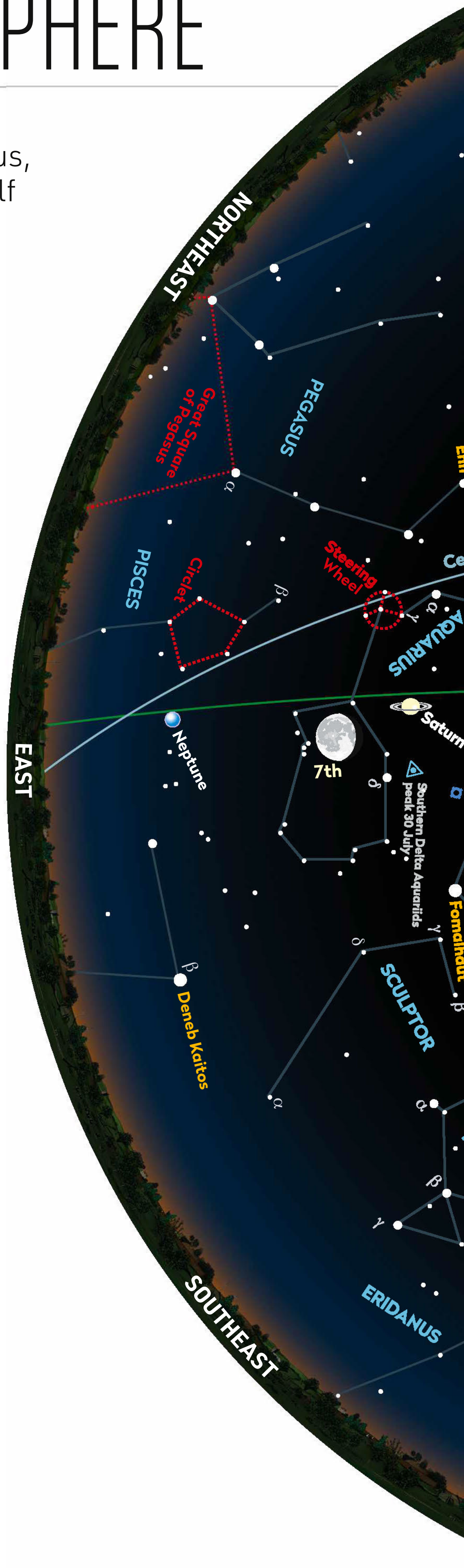
This month, a trip to the constellation of Lupus, the Wolf. Phi¹ (ϕ^1) Lupi (RA 15h 21.8m, dec. –36° 16') with Phi² (ϕ^2) makes a naked-eye double star with components of mag. +3.5 and +4.5, separated by 43 arcminutes. Binoculars reveal an attractive colour difference, Phi¹ being yellow and Phi² being blue-white.

Next, two quite different globular star clusters. The most striking feature of NGC 5986 (RA 15h 46m, dec. –37° 47') is its bright, wide, 5-arcminute core surrounded by a narrow, fainter halo about 1 arcminute across. Stars are visible scattered across this mag. +7.5 globular. In contrast, NGC 5824 (RA 15h 4m, dec. –33° 4') has a faint halo of around 3 arcminutes, with an almost stellar-like core of around 1 arcminute. Only a few stars are resolved around the edge and they call for a larger telescope (around 250mm) to be seen.

Chart key

GALAXY
OPEN CLUSTER
GLOBULAR CLUSTER
PLANETARY NEBULA
DIFFUSE NEBULOSITY
DOUBLE STAR
VARIABLE STAR
COMET TRACK
ASTEROID TRACK
METEOR RADIANT
QUASAR
PLANET
STAR BRIGHTNESS:
MAG. 0 & BRIGHTER
MAG. +1
MAG. +2
MAG. +3
MAG. +4 & FAINTER

CHART: PETE LAWRENCE




NORTH
DRACO
HERCULES
M92
Keystone
M13
CORONA BOREALIS
BOÖTES
NORTHWEST
Kite
Arcturus
Deneb
NGC 7000
CYGNUS
Summer Triangle
LYRA
Vega
M29
Northern Cross
M57
Albireo
Veil Nebula
VULPECULA
M27
M71
Collinder 399
Rasalgethi
Rasalhague
DELPHINUS
SAGITTA
M15
EQUULEUS
Altair
AQUILA
IC 4665
SERPENS CAPUT
OPHIUCHUS
SERPENS CAUDA
M5
Celestial Equator
M14
M12
M10
Alpha Capricornids peak 30 July
M11
Coffin
M2
NGC 7009
SCUTUM
M17
M107
VIRGO
M25
M9
Ecliptic
M8
M75
Pluto
M22
30th
1st
LIBRA
4th
M55
M19
M6
27th
WEST
CAPRICORNUS
Teapot
M7
M62
Antares
Spica
24th
M30
Piscis Austrinids peak 28 July
NGC 5986
NGC 5824
MICROSCOPIUM
SAGITTARIUS
CORONA AUSTRALIS
SCORPIUS
LUPUS
NORMA
CORVUS
PISCIS AUSTRINUS
GRUS
INDUS
ARA
PAVO
TRIANGULUM AUSTRALE
ω Cen
M68
Rigel Kentaurus
HYDRA
CENTAURUS
TUCANA
CIRCINUS
PHOENIX
OCTANS
APUS
NGC 4755 Jewel Box
Coalsack
47 Tuc
SMC
CRUX
MUSCA
Achernar
IC 2944
South Celestial Pole
CHAMAELEON
HYDRUS
Colinder 240
NGC 3532
Southern Pleiades
SOUTHWEST
MENSA
CARINA
ANTLIA
Miaplacidus
Eta Carina Neb
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NGC 2070
LMC
VELA
VOLANS
False Cross
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